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SIZE-REDUCTION EQUIPMENT FOR MUNICIPAL SOLID WASTE

VOLUME I. PROCEDURES FOR EVALUATING AND COMPARING
EQUIPMENT

VOLUME II. INVENTORY OF EQUIPMENT

MIDWEST RESEARCH INSTITUTE

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SIZE-REDUCTION EQUIPMENT FOR MUNICIPAL SOLID WASTE

Volume I: Procedures for Evaluating and Comparing Equipment
Volume II: Inventory of Equipment

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SIZE-REDUCTION EQUIPMENT FOR MUNICIPAL SOLID WASTE

VOLUME I

STANDARDIZED PROCEDURES FOR EVALUATING AND COMPARING SIZE-REDUCTION EQUIPMENT

CHAPTER I

INTRODUCTION

A. Background

The Solid Waste Disposal Act of 1965 has concentrated considerable interest on the question of what to do with the huge quantities of municipal solid waste generated in the United States each year. Recent activity has centered on the utilization of this great quantity of material as a national resource. Thus, emphasis in solid waste management has changed in recent years from disposal to recovery, recycling, or reuse. Many systems for the recovery and reuse of solid waste require that the waste components be physically separated from each other and that a reduction in the particle size of the waste precede recovery or reuse operations. Even in those geographic areas where disposal will continue to be the only economic solution to the solid waste problem, size reduction may increase the capacity of the disposal system.

Size reduction is an operation that is common to many solid waste management systems—reuse, recovery, or disposal. It is also an operation that can be accomplished with off-the-shelf commercially available equipment. Thus, size reduction is a logical starting place for a comparative study of solid waste management systems or equipment. This report presents the result of a study to develop a standardized procedure for the comparison and evaluation of size reduction equipment.

B. Objective of the Study

The objective of this study was twofold: (1) to compile an inventory of current manufacturers and users of solid waste size reduction equipment; and (2) to develop a comprehensive procedure for evaluating and comparing equipment used for size reduction of solid waste. This report is intended for use by administrative personnel (or other equipment purchasers without technical backgrounds) as an aid in the comparison, evaluation, and selection of equipment. It will also be incorporated into a state-of-the-art report on size reduction and a selection criteria document for use by solid waste management organizations.

C. Technical Approach

A three-phase effort was used to meet the objectives of the study. Phase I was a collection of data and information on current size reduction equipment and manufacturers. Phase II was a development of a numerical rating procedure for the comparative evaluation of size reduction equipment. Phase III was a development of a test procedure to generate base-line, technical, economic, and performance data needed for the numerical rating procedure.

1. Phase I-Equipment Inventory. "An Inventory of Municipal Solid Waste Size Reduction Equipment," was previously presented by MRI in a separate report to EPA dated 2 October 1972. The report includes a general background of size reduction equipment, design, a discussion of the sources of information for the inventory, selection guidelines based on the experience of operators of municipal solid waste size equipment, data sheets from each of the manufacturers and suppliers of size reduction equipment, and a listing of solid waste processing or disposal facilities that include size reduction in their system.

2. Phase II-Numerical Rating Procedure. In the process of gathering data for the inventory of Phase I, numerous contacts were made with operators, users, consultants, sellers, and manufacturers of size reduction equipment. The information gained from these contacts was combined with the knowledge of the MRI project staff to develop a list of the factors to be considered in selecting size reduction equipment. This list was reviewed by the project staff to develop a preliminary model of the rating system. The preliminary model was then reviewed in detail with knowledgeable persons in the field of size reduction. Their comments were incorporated with the preliminary model into the final model of the Numerical Rating Procedure.

3. Phase III-Test Procedure. Several factors in the Numerical Rating Procedure required comparison to performance norm's (i.e., "base-line" data). In many instances the base-line data will not exist, or are not available because they are proprietary. Thus, a plan was developed to use existing EPA demonstration grant or pilot plant projects to develop sufficient base-line data for use with the Numerical Rating Procedure.

The following chapters present the results of this project. Chapter II includes a definition of the role of size reduction in solid waste management and a brief description of the equipment used. Chapter III discusses the general guidelines for developing a basic design for a size reduction facility. Chapter IV presents the Numerical Rating Procedure. Chapter V reports the test procedures to be used to develop the base-line data for size reduction machinery. Chapter VI presents the results, conclusions, and recommendations of the study.

CHAPTER II

SIZE REDUCTION OF MUNICIPAL SOLID WASTE

A. Introduction

Size reduction is defined as operations or processes which reduce the size of influent materials through division into two or more subunits. For the purpose of this study, only size reduction by the application of mechanical forces is considered. Size reduction of municipal solid wastes (often called shredding, grinding, or pulverizing) is a new concept and much of the technology has been borrowed from the mining and rock-crushing industry. Because solid waste is a heterogeneous mixture (unlike rock), much of the technology is not directly transferable and size reduction of solid waste has not been efficient or widely practiced. However, as more solid waste systems are built, the technology of solid waste size reduction is being advanced.

B. Reasons for Size Reduction in Solid Waste Management

More than 300 billion pounds of municipal waste are produced annually in the United States and the traditional methods of disposal are becoming inadequate. Land areas suitable for landfill near urban areas where the bulk of the solid waste is generated are becoming scarce and expensive. Open burning and open dumping have been outlawed in many areas because of pollution and health hazards. Incineration is becoming increasingly more expensive because of sophisticated pollution control equipment required to meet acceptable air quality standards. Current emphasis in solid waste management, therefore, has centered on both disposal of this great quantity of material and its utilization as a national resource. The volume of waste produced each year dictates that disposal or recovery of the waste be mechanized to reduce ever increasing costs. This has, in turn, created a need for size reduction of solid waste to accomplish reduction of bulk and permit easier mechanical handling.

Current research and development work in solid waste management technology is concerned with resource recovery. Numerous resource recovery systems have been proposed and pilot plants have been built in some instances. These recovery systems can be grouped into two classes—materials recovery systems and energy recovery systems. In many of the proposed recovery systems size reduction is one operation that is common. Size reduction does not in itself increase the value of the waste, but it may reduce bulk and increase ease of handling. These features make size reduction a desirable feature of solid waste management.

1. Bulk reduction: Prior to size reduction, municipal solid waste has a low and nonuniform density. Size reduction increases the heterogeneity and the bulk density. The process of size reduction yields a smaller range of particle sizes, and thoroughly mixes the solid waste. The net result is that the waste can be easily compacted to a uniform density, and voids formed by bulky items are eliminated. The amount of reduction in bulk can vary depending on the final processing of the waste; however, discussions with landfill operators has indicated that shredded waste placed in a landfill and compacted in a manner similar to unshredded landfill, can have the density increased by up to 25% over that of unshredded landfill.

It is the bulk reduction and mixing of the waste that gives size reduction its most promising potential for immediate application. Solid waste that has been shredded and compacted generally has fewer voids than unshredded landfill, has no objectionable odor, does not attract vermin, and has been used in landfill without a daily cover of soil on an experimental basis. The combined effect of the elimination of the daily cover and the bulk reduction can increase the solid waste mass capacity of a landfill area by a factor of two or more.

2. Ease of handling: Size reduction of solid waste is of major importance in many solid waste processing systems because it permits more efficient handling of the waste. Shredded waste has a smaller range of particle size, is uniform in density, and is a more homogenous mixture, thus permitting it to be easily handled and processed by mechanical equipment. The mechanical and chemical processes used by most recovery systems require separation of various components. This separation is easier and more efficient when particle size range is controlled.

C. Size Reduction Equipment

There are 10 basic types of size reduction equipment commercially available--crushers, cage disintegrators, shears, shredders, cutters and chippers, rasp mills, drum pulverizers, disk mills, wet pulpers, and hammermills. Of these types we believe that only hammermills and wet pulpers will be important for future application in either primary or secondary municipal solid waste size reduction. To date, only hammermills and wet pulpers have been used in the United States, although the rasp mill has been used in Europe. Further details on the designs of each type of equipment can be found in Ref. 1. Only the hammermill and wet pulper types will be discussed in this report.

1. Wet pulpers: A wet pulper is similar in design and operation to a common household blender. In operation, a slurry of about 90% water and 10% solid waste is placed in the pulper. The interior of the pulper may be lined with protruding hardened impact pins, but often the interior is a smooth surface. A central rotating element (either a disk or a set of blades) spins at high speed (peripheral speed of 5,000 ft/min) forming a vortex in the slurry. Repeated impact of the solids with the rotating element reduces the solid waste to a pulp. Unpulvable items, such as rubber tires are

rejected. Wet pulpers can operate as a batch process or a continuous process. After pulping the slurry is removed from the pulper and the majority of the water is removed by squeezing and is reused.

The use of a wet pulper for size reduction has not found widespread acceptance. Many experts object to the concept of adding water and then removing it after size reduction. Only one facility using a wet pulper to process solid wastes is in operation in the United States. The plant is located in Franklin, Ohio, and uses the Black-Clawson hydropulper. The Franklin plant is a small pilot plant having a capacity of 6 tons/hr. Larger plants have been proposed; however, their plans usually include the use of a mechanical shredder ahead of the pulper to increase pulper efficiency and to reduce wear and possible damage to the pulper.

2. **Hammermills:** The most common type of equipment currently used for size reduction of solid waste is the hammermill. A hammermill consists of a central rotor with radial arms (hammers) protruding from the rotor circumference. The rotor is enclosed in a heavy duty housing and the housing may be lined with hard metal members. Some hammermills may also have stationary breaker plates or cutter bars mounted inside the housing. Input material is reduced in size by being mechanically beaten and torn by the hammers.

There are two basic types of hammermills--the horizontal shaft type and the vertical shaft type. The horizontal shaft hammermill is the more common type. As the name implies, the rotor shaft is horizontal and supported on each end. Input is at the top and material flows through the machine by gravity. Most horizontal hammermills also have a grate placed across the output opening. Input material cannot pass through this grate until it has been sufficiently reduced in size. Output particle size is primarily controlled by the size of openings in the grate.

The vertical shaft hammermills have the rotor shaft placed in a vertical position. The input material moves parallel to the shaft axis and flow is by gravity. The lower shaft bearing must be a thrust bearing to support the weight of the rotor. These machines may have a decreasing cross-sectional area between the rotor and the stationary housing. Thus, size reduction of the input is progressive as the material moves through the machine.

There are three basic variations of both the vertical or horizontal shaft hammermills--the swing-hammer type, the rigid-hammer type, and the rolling-element type. The swing-hammer type is the most common, and has hammers free to pivot mounted on pins. The swing-hammer concept reduces damage to the machine from hammer impact with a very hard or strong piece of input material. However, the hammers can also create a severe balance problem if they become entangled with the input material and do not swing freely. The rigid-hammer type is generally used in smaller sized machines not specifically designed for solid waste. For both the fixed- and rigid-hammer types, hammer designs

vary from sharp choppers to blunt rectangular beaters. The latter are often used in machines for processing solid waste materials. In rolling-element type machines, the hammers are usually in the form of star wheels which grind up the input refuse by rolling it between the wheels and the housing side walls.

D. Wet vs Dry Systems

The hammermill and the wet pulper represent two different concepts in solid waste size reduction--the dry system (the hammermill) and the wet system (the wet pulper). For any given solid waste management system, the two concepts are not interchangeable; that is, in any given size reduction system you cannot directly replace one with the other. The wet system requires extensive auxiliary equipment for addition and removal of the water, and this equipment is not needed by the dry system. In addition, the wet system is more expensive and it is therefore only usually considered where recovery of a salable product is concerned. Also, most of the proposed wet systems using a wet pulper have included in their plans a "solid waste shredder" ahead of the pulper to increase efficiency and prevent damage. Because of its limited use, the wet system, or wet pulper, was not considered a primary method of size reduction and was not included in further efforts of the program.

CHAPTER III

SOLID WASTE SIZE REDUCTION FACILITY DESIGN

A. Introduction

The use of size reduction equipment to process municipal solid waste is an emerging technology. As a result, many of the installations now operating in the United States are small pilot-plant operations, and many were largely supported by government funds. Because of the newness of the technology, there is no accumulated body of formal knowledge. Each new installation thus draws heavily on the experience of earlier installations. However, several general trends in plant layout and design have been developed and some of them are already accepted as standard. This chapter presents a brief discussion of the current state of the art for design of size reduction facilities. The information contained in this chapter was obtained from personal visits to many of the solid waste processing installations now in operation, from discussions with knowledgeable people, and from a review of the pertinent literature. Any plants or installations referred to in the discussion are described in further detail in the report entitled, "An Inventory of Municipal Solid Waste Size Reduction Equipment" (Ref 1).

B. Size Reduction as Part of a System

A solid waste size reduction facility is only one part of a system of solid waste management. As such, the facility must be integrated into the system and designed to fit the needs of the system. Before the size reduction facility can be designed, it is first necessary to know the characteristics of the solid waste. Then the role that size reduction is to fill in the solid waste management system can be determined, and the technical and economic performance requirements of the facility can be specified.

There is a variety of solid waste management systems now being used or developed in the United States. They range from the simple open dump, through the common sanitary landfill, to the technically complicated total recovery or reuse system (i.e., Franklin, Ohio). However, all of these systems can be grouped into one of two general categories—those systems where disposal is the primary goal, and those systems where recovery, recycling, or reuse is the primary goal. Table 1 presents a summary of the more common systems.

TABLE 1

SOLID WASTE MANAGEMENT SYSTEMSDisposal Systems

Landfill

Incineration

Recovery, Reuse, or Recycle Systems

Energy

Materials

Pyrolysis

Compost

Size reduction of the solid waste can be used to increase the efficiency of each of the systems listed in Table 1 by (1) reducing bulk, (2) providing a narrow range of particle size, and (3) thoroughly mixing the waste (however, size reduction may be detrimental to grate-type incinerators). Further, the size reduction facility can be designed so that it will affect each of these factors to the degree required for optimization of system efficiency. Therefore, size reduction is a "service" component of the system—i.e., it does not determine what the operation parameters of the system are, it simply adjusts the physical characteristics of the solid waste to optimize the efficiency of the system.

An important step in designing a solid waste size reduction facility is to determine what functions the facility is expected to perform in the solid waste management system. This involves determining what input the facility will receive and what output it is expected to deliver. Of the two-input and output—an exact definition of the output requirements is the more critical, for the output requirements determine the performance specifications for the size reduction facility—capacity in tons per hour, output particle size, composition, etc.

C. Design of a Typical Size Reduction Facility

Once the input and output requirements of the size reduction facility have been determined, the basic design of the facility can be developed. The following paragraphs describe a typical solid waste size reduction facility utilizing the most recent state-of-the-art concepts.

The functions of a typical facility are shown in the block diagram flow chart of Figure 1 and the facility layout is shown in Figure 2. The facility consists of the following basic operations:

1. Receiving and holding—receiving input waste, premixing, sorting, separation of bulky items, temporary storage for processing;

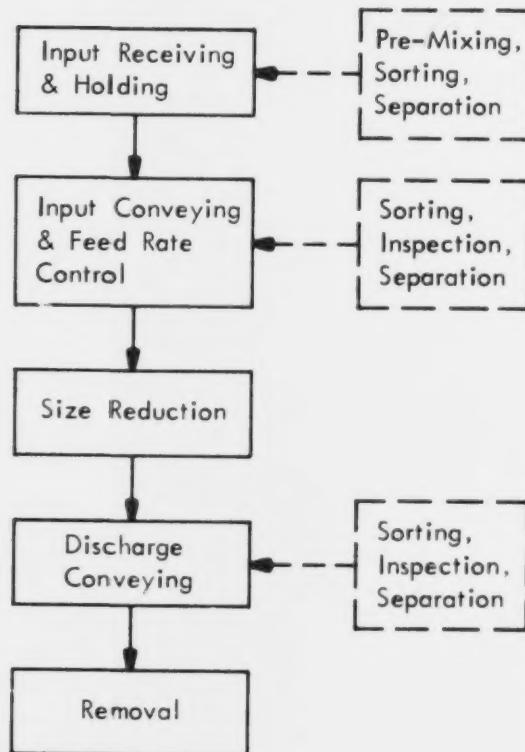


Figure 1 - Size Reduction Facility Flow Chart

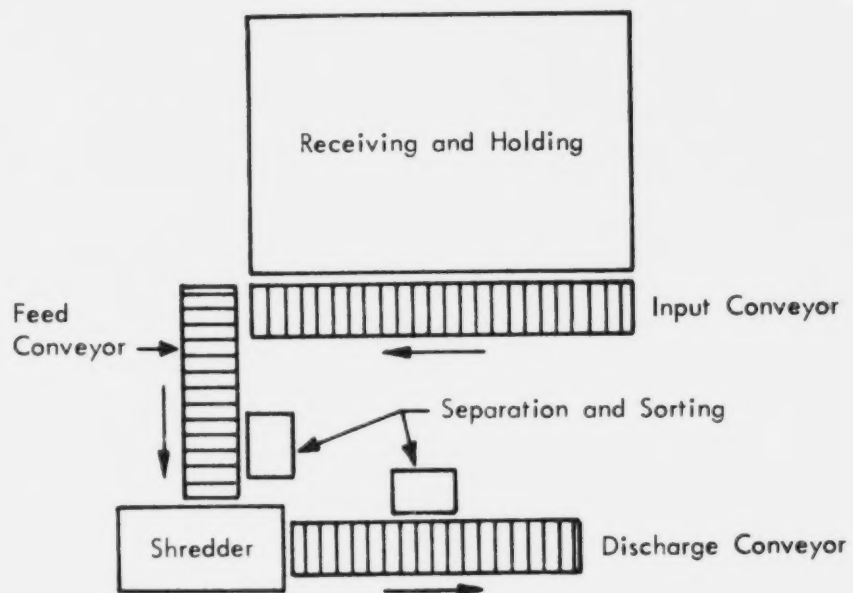


Figure 2 - Typical Size Reduction Facility Layout

2. Input conveying-material transfer, inspection, sorting, separation;
3. Feed control-material flow rate control;
4. Size reduction-shredding of the solid waste;
5. Discharge conveying-material transfer, separation of unwanted components; and
6. Removal-disposition or disposal of shredded waste.

1. Receiving and holding: The receiving and holding area of the size reduction facility serves the function of accepting the input of solid waste from the refuse collection system (usually packer trucks), and storing the material until it is processed by the shredder. This function is necessary because the input is usually in batches (i.e., individual packer trucks) with variable quantities of waste at different times. However, maximum efficiency of the shredder usually requires continuous feeding at a uniform rate. Thus, a buffer or temporary storage is needed between the waste collection and the shredder operations.

The most successful procedure developed for receiving and handling the input solid waste material has been the open receiving pad. The open receiving pad is simply an open, level and paved area adjacent to the waste shredder. In some installations, the pad is enclosed so that operations are not affected by bad weather. Packer trucks deposit the waste on the pad at the direction of an operator. The pad operator uses a bucket-equipped hi-loader, or other piece of waste moving equipment, to pile and mix the waste, and to place the waste on the input conveyor. The operator controls the feed rate to the shredder by the amount of waste he places on the conveyor. He can also increase the efficiency of the shredder by mixing the waste, and distributing bulky and difficult-to-process items throughout the waste.

The open receiving pad has proven to be the most successful input system because it provides an easy and economical means of presorting and mixing the input waste. Although municipal solid waste is generally considered to be a heterogeneous mixture, it is not a thorough mixture as received, and it will have occasional bulky items, such as appliances or pieces of furniture. There will also be difficult-to-shred items such as tires, rolled-up rugs, tree trunks, heavy metal pieces, etc. Any of these items can cause trouble for almost any size or type of reduction machine. With an open receiving pad, the operator can easily remove the items that he does not want to enter the machine, distribute the remainder of the bulky items, and thoroughly mix the refuse before feeding it to the shredder.

Other input receiving systems have been tried but have generally not been as successful as the open receiving pads. One frequently used procedure has been to have the packer trucks discharge the waste directly into a feed hopper or storage bin. Both of these techniques have proven troublesome because the unshredded waste tends to bridge and to jam hoppers and is difficult to feed continuously and uniformly from a storage pile. Another common system is to discharge the waste from the packer trucks directly onto the shredder input conveyor. This system subjects the input conveyor to considerable abuse and causes uneven feeding of the shredder--sometimes producing motor overloads, machine jamming, and shutdowns.

2. Input conveying: Input conveying consists of those components of the facility that transfer the solid waste from the receiving and holding area to the shredder. It is in the conveying operations where material flow rate is established and initial mechanical separation is performed. The input conveying will frequently consist of two or more conveyors--the input conveyor that receives material directly from the receiving pad, and the feed conveyor(s) that changes the elevation of the material and feeds the material into the shredder.

a. Input conveyors: Heavy duty metal pan-type conveyors have proven to be the only reliable type of input conveyors. The input conveyors receive considerable abuse, mainly due to dropping and dumping of the solid waste into the conveyor. Operating life of flexible belt conveyors has, in general, not been adequate in this application (one exception is St. Louis, which has obtained satisfactory performance with a flexible belt). The typical input conveyor arrangement places the conveyor in a horizontal position at the bottom of a feed trench. The trench is approximately 5 ft. deep with inward sloping sides. The solid waste material is simply pushed off the receiving pad into the trench where it then falls onto the input conveyor.

The input conveyor normally operates at a fixed speed and the waste feed rate to the shredder is adjusted by the depth of waste the operator places in the trench. Several installations have installed variable speed conveyors, but experience has shown that only one speed is used in actual operation. However, the input conveyor should be interlocked to the feed conveyor and they both should be electrically interlocked to the shredder motor. These interlock will stop the conveyors if the shredder motor overloads. This gives the shredder an opportunity to clear itself before receiving additional input that could cause a jam.

b. Feed conveyors: Flow through a shredder is generally by gravity and thus is vertical. Therefore, it is necessary to raise the waste to the input opening of the shredder. This is usually accomplished by an inclined feed conveyor. The inclined conveyor can be a flexible or rubber belt conveyor since this conveyor

is not subject to the abuse that the input conveyor receives. A common problem with many inclined conveyors is the tendency of the waste to slide back down the conveyor. This problem can be minimized by using less slope or a belt with a textured surface or with cleats. One such example is the Z-bar conveyor used at the New Castle County, Delaware, facility.

c. Sorting and separating: Some amount of separation of the waste can be done at the input and feed conveyors. Separation at this point is usually a protective measure designed to prevent undesirable materials from entering the shredder. Because of the depth of material on the conveyors, the presence of numerous closed bags and boxes, and the tangled nature of the material before shredding, a thorough separation is not practical. Magnetic separation or a metal detecting system can be used to prevent large pieces from entering the shredder. However, the generally accepted procedure is to sort undesirable items at the receiving area and have an operator visually monitor the input conveyor directly ahead of the shredder. The operator will manually remove any undesirable material he detects.

3. Feed control techniques: Control of the rate at which the solid waste is fed to the shredder is probably the most important aspect of daily operation of a size reduction facility. Feed rate control is of major importance because it has a large effect upon the efficiency and life of the shredder. It is also difficult to perform accurately and reliably. Several techniques have been tried and all have achieved only limited success. Several of the more common techniques are discussed in the following paragraphs.

a. Vibratory feeders: The vibratory feeder has long been used in the ore and rock-crushing industry to feed aggregate material of variable composition. It will agitate the input and tend to distribute it evenly over the feeder surface. It thus tends to "smooth out" variations in flow rate. One example of a vibratory feeder installation for solid waste is at the St. Louis, Missouri, Refuse Plant. A diagram of the installation is shown in Figure 3. The vibratory feeder is installed in the bottom of a trench with sloping sides. The feeder is shorter than a normal input conveyor and can be fed from three sides. The waste material is simply pushed off the pad and onto the feeder which then feeds the inclined belt that raises the solid waste to the shredder input. Structural problems from the vibrations have occurred with this installation, however, and a flexible belt unit has replaced the vibratory feeder.

b. Leveling bars: Leveling bars, or "doctor" blades, have also been used with an input conveyor to control the depth of waste on the conveyor. In general, these devices have not been successful because of the tendency of the waste to jam, bridge, and hang up on items caught on the bar or blade. One successful application has been at the Milford, Connecticut, plant. This installation has a direct feed from the input conveyor

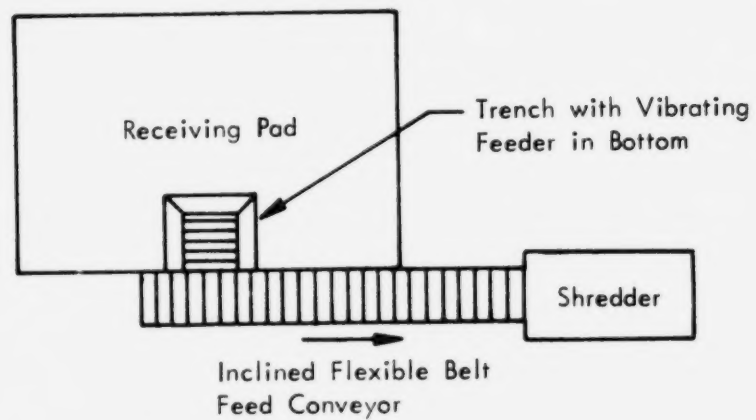


Figure 3 - Layout of St. Louis, Missouri, Solid Waste Size Reduction Facility

to a shredder mounted in a pit. A hydraulically operated blade is located over the input conveyor just ahead of the shredder. An operator continuously monitors the input and controls feed rate to the shredder by adjusting the height of the blade. Minor jams at the blade are frequent, but they are easily controlled by operator action.

c. Compression feed rollers: Several manufacturers of size reduction equipment offer, as an optional device, an input compression feed roller. This device is simply a roller that compresses the input waste and literally "force feeds" it into the machine. It usually has a hydraulic power drive with a variable speed control. This device serves three functions:

- (1) It controls the rate of feed;
- (2) It physically "grabs" the waste and prevents the shredder from pulling too much material from the feed conveyor, and possibly jamming itself, and
- (3) It obstructs the input opening and reduces "backfire" or ejection of material out the input opening.

Several manufacturers recommend the use of a compression feed roller (to protect their machine from bulky objects) and some require one to be included before they will submit a bid. However, the devices have not been found to improve performance enough to justify their high cost, and are not used in most installations.

4. Size reduction equipment: The size reduction equipment consists of those components of the system directly involved in the physical application of the size reduction force to the input waste. The components include the shredder, the drive motor, the motor controls, and the related auxiliary equipment. The following paragraphs include a discussion of some of the factors to be considered in designing the shredder installation. Technical considerations in sizing the shredder and motor capacity are presented in Section D of this chapter.

a. Shredder installation: Three concepts for physical location of the shredder are in general use. They are: (1) below ground (in a pit); (2) at or above ground level; and (3) on the side of a hill. All three concepts have been used successfully and neither has a distinct advantage over the others. Oftentimes the choice of installation is determined by site restrictions or geography rather than by technical or performance factors.

Installation of the shredder at ground level is the simplest and the most common type of installation. The shredder is usually mounted on a concrete base and has easy access for all sides. The major disadvantage with this type of installation is that it requires an inclined feed conveyor to lift the waste to the shredder

input. A unique approach to this problem, used by Ecology, Inc., Brooklyn, New York, was to put the input receiving pad on the roof. The inclined conveyor was thus eliminated and the shredder feed is directly from the input feed conveyor. This approach has an obvious appeal for facilities located in congested urban areas where space for a receiving pad is at a premium.

Installation of the shredder below ground or in a pit is a concept that has been used at several installations. The logic behind this choice is that noise is significantly reduced, and plant personnel are protected from fires or explosions that may occur due to flammable materials in the waste and also from flying debris from the shredder. There is also the consideration that the inclined conveyor is moved from the input to the output (to lift the waste out of the pit) thus resulting in a cost savings because of the less complicated equipment required for conveying the shredded waste. However, access to the shredder for maintenance becomes limited, especially for horizontal shaft hammermills. These units are usually designed so that removal of the top housing is required for access to the hammers. Thus, if installed in a pit, the overhead chutes and conveyors must be removed for access. Vertical shaft hammermills do not have this problem as they usually have side access doors and can be easily serviced in a pit. For either type of unit, major repair (i.e., removal of a rotor or motor, etc.) requires a crane to lift components out of the pit. Examples of plants with the shredder mounted in a pit are Milford, Connecticut, and San Diego, California.

If the plant site has a hill or a pronounced slope, it may be wise to mount the unit on the side of the hill. The input pad is then located at the top of the hill and the discharge area is located at the bottom. The inclined conveyors are eliminated and the shredder feed is directly from the input conveyor. Although this concept has an obvious appeal in simplicity and equipment cost saving, structural costs may be increased if the plant is to be enclosed. Examples of facilities built on the side of a hill are Tacoma, and Vancouver, Washington.

b. Shredder type: There are two types of shredders currently available--the horizontal shaft type and the vertical shaft type--and the horizontal shaft hammermill is by far the more common type of machine. Both types of machines operate at about the same mechanical efficiency (power per ton) and both types of machines have generally been successful. However, there are some distinct differences in their performance, especially in relation to output particle size control, handling of difficult to shred items, wear rates, and surge capacities.

(1) Particle size control: The horizontal shaft hammermill has a positive control over maximum output particle size. All input material will remain inside the machine until it is

sufficiently reduced in size to pass through the discharge gate. Thus, only minor variations in particle size will occur with changes in material flow rate or composition. This factor can be of critical importance if the shredded waste is to be used in a system where maximum particle size is important, i.e., a pneumatic feed burner. The disadvantage is that the horizontal shaft hammermill is not a "free-flowing" shredder and is thus subject to high wear rates and is easily overloaded.

The vertical shaft hammermill does not necessarily have positive control over particle size. Thus, a unique feature of these machines is that the average output particle size will change as the flow rate or material composition changes. Although this factor would appear, at first glance, to be a disadvantage, for systems that do not require accurate particle size control, it may be of minor importance.

(2) Shredding of difficult items: Because the horizontal shaft hammermills have a restricted discharge (i.e., an output grate) they are subject to damage from difficult to process items. The shredder will "try" to reduce the item to the output size or to "extrude" it through the grate. Items such as heavy steel, rolled-up rugs, large tree limbs, etc., which require power inputs beyond the capabilities of the machine, can cause jams. Thus, for these machines, presorting of input material and separation of undesirable items is required.

These machines normally have metal traps where heavy steel or other nonprocessable items are collected, but these devices are not reliable protection devices. A hardened gear, for example, may make numerous revolutions in the machine, damaging hammers, levers and grates, before it enters the metal trap. Metal traps must be manually emptied at regular intervals.

The vertical shaft machine, on the other hand, is much less subject to damage because it will pass difficult items through the machine. This means that presorting of the input can be less thorough and only obviously undesirable items that are physically too large to pass through the machine opening need be separated. However, it is possible that some items may go through the machine with only minor reduction in size.

Neither type of machine will satisfactorily process items with high tensile strength such as rolled-up rugs, yard goods, etc. Also, both machines are subject to jamming by rope-like items such as cable, wire, bedsprings, tubing, etc. These items can wrap around the rotor and create unbalance problems.

(3) Wear rates: The vertical shaft hammermills usually operate on a progressive size reduction principle, i.e., the input material is gradually reduced in particle size as it passes

from input to discharge. Several operators claim, therefore, that the vertical shaft hammermill has a more even distribution of wear than the horizontal shaft hammermill and significantly lower hammer wear rates. These claims have not been substantiated; however, the trend of the limited data available indicates that the vertical shaft hammermill may have lower hammer wear rates than a horizontal shaft hammermill.

c. Drive motors: Most size reduction equipment designed for shredding municipal solid waste requires a main drive motor in the range of 500 to 1,500 hp. The electric motor is the most common type of motor selected, although diesel drives have been proposed for some installations. A major factor to consider in choosing the motor type is installation cost. A typical large size electric motor draws substantial current and power companies will require that a separate substation be installed. If the size reduction facility is located at a remote site, the cost of providing electrical service can become a significant part of the total capital investment. In such cases, diesel power units may be more cost effective.

The usual procedure for connecting the drive motor to the shredder is direct drive, i.e., the motor shaft is coupled directly to the shredder rotor shaft. This procedure is generally the most simple and least expensive connection that can be made. Almost all manufacturers of horizontal shaft hammermills recommend direct coupling. However, one manufacturer does use a belt drive from the motor shaft to the rotor with a large flywheel mounted on the other end of the rotor. There does not appear to be any significant problems with the belt drive system, although it is more complicated than the direct drive. The belt drive does allow some flexibility in motor locations, and may be advantageous in locations where space is at a premium.

The vertical shaft hammermills generally use a gear or belt drive system. Direct coupling of the motor shaft to the vertical rotor is not practical. Thus, for most vertical shaft hammermills, the motor is located along side the unit and a gear drive unit is utilized. One manufacturer, EIDAL, uses the gear box as an integral part of the shredder structure. Gear units, depending on specific designs, will require additional support equipment (such as lubricant pumps and temperature control devices), that are not required for direct or belt drives. They will also increase the maintenance of the shredder facility.

d. Motor controls: In addition to the necessary motor switch gear, installation of several other items of control instrumentation is becoming standard procedure. These items include indicating and recording power meters, input and discharge conveyor interlocks, and bearing temperature interlocks.

Indicating amp-meters are a standard item at most shredder installations. The amp-meter indicates the motor current draw

and is the easiest way to determine overloads. The operator can watch the amp-meter and adjust the feed rate to obtain maximum efficiency of the shredder. Many installations have indicating or warning devices connected to the amp-meter to signal the operator when overloads occur. Several installations have recording amp- or watt-meters. These are not considered necessary and are only used when continuous records of power consumption are desired.

Drive motor interlocks to the input conveyor are becoming the standard device for protecting the shredder and drive motor from overloads. These devices stop the input conveyor when the shredder drive motor overloads. This prevents further feeding of material into the shredder, reduces the load, and gives the shredder an opportunity to "clean out" a potential jam before it occurs. Standard design procedure is to have an automatic cutoff that stops the input conveyor with the restart being manual, thus requiring operator attention to the cause of the stoppage. Many operators of size reduction facilities consider the drive motor-input conveyor interlock the single most important automatic control in the entire facility. Even those installations that did not originally include the interlock have now installed them because damage to the shredder and drive motor has resulted from overfeeding.

The shredder bearing temperature sensor is another protective device that is gaining wide acceptance. At most installations, the device is designed to issue a warning if the shredder bearing overheats, and it will continue to give the warning until the temperature returns to the safe range. The warning tells the operator to stop the feed conveyor and reduce the load on the shredder (and bearings) until the temperature drops. Some installations have included a bearing temperature interlock that will turn off the shredder drive motor if the bearings continue to overheat or exceed a critical temperature.

e. Auxiliary equipment: Most manufacturers offer several optional items or pieces of auxiliary equipment that can be purchased with the shredder. Some of the more desirable ones are discussed below.

(1) Power assist devices: Any shredder that has a pressurized bearing lubrication system, has the basis for hydraulic power assist devices. These devices include:

-Power cylinders for opening assist doors: These items are especially helpful on horizontal shaft hammermills where access to the hammers requires opening the top housing. Several manufacturers include these door openers as standard equipment.

-Hammer pin extractors: These devices are used to pull the hammer pivot pins from their mounting so that worn hammers may be replaced. These devices are most helpful as it is difficult to manually remove the hammer pins after extensive use of the shredder.

External adjustments for wear: Several hammermills have stationary breaker bars or cutter bars whose clearance with the hammers can be adjusted from outside the shredder. Standard equipment for these shredders is manual adjusters, however, hydraulic adjusters are available and have been well received by operators who have used them.

(2) Fire control systems: Due to the high percentage of flammable materials in municipal solid wastes, fires in the shredder are a common occurrence. Normally, a fire can be "snuffed out" by continued feeding of the shredder; however, fires associated with jams or stoppages must be extinguished. Manually activated carbon dioxide or water extinguisher systems are available and are recommended.

(3) Dust control systems: Dust and small particle debris are a constant problem around a solid waste shredder. Two techniques are used to control and minimize the problem. The simplest procedure is to use a continuous water spray inside the shredder. The water reduces the amount of dust generated and causes most debris to exit the shredder with the discharge. There are some experts who believe the water also reduces the wear on the hammers.

Pneumatic dust collectors are the other form of dust control technique used. They are most often used in systems where the shredded waste is being used in an incinerator or boiler and any water content is undesirable.

5. Discharge conveying: The discharge conveying elements of the shredder serve the function of collecting the shredded waste from the shredder and conveying it to the removal or disposal area. There are normally two elements to the discharge area—the discharge chute or collector and the discharge conveyor.

a. The discharge chute: The shredded waste material being discharged from the shredder may possess considerable energy and be moving at high velocities. Therefore, it is not practical to discharge directly onto a conveyor. For horizontal shaft hammermills with bottom discharge, a simple chute or deflection plate is placed directly under the discharge and absorbs most of the energy from the waste. The waste then slides down the chute or plate onto the discharge conveyor. However, it is possible for the waste to "stick" to the chute and cause a jam. To avoid this potential problem, the chute or deflector plate can be replaced by a vibrator conveyor. The vibratory conveyor can take the abuse and impacts from the discharged waste and still provide a positive method of carrying the waste away from the shredder.

b. Discharge conveyor: The discharge conveyor transports the waste from the shredder to the removal or disposal operation of the size reduction facility. This conveyor is usually a flexible belt that moves at a much faster speed than the input conveyor. A flexible belt

conveyor can be used in this application because the shredded waste has a homogenous composition and contains no bulky objects to subject the conveyor to abnormal physical abuse. The conveyor moves at a faster speed to assure that the discharge of the shredder is always clear. The speed may cause blowing and strewing of the waste so conveyor sides and covers are frequently used.

c. Separation: If separation of the waste products is required for subsequent operations, it is usually done at some location in the discharge conveyor system. At this point the waste is shredded, has a narrow range of particle size, is not very deep on the conveyor, and has not been compacted or compressed. A wide variety of separation devices including magnetic, pneumatic, and vibratory can and have been used. A thorough discussion of separation techniques can be found in Ref. 2.

6. Removal or disposal: The final operation of the size reduction facility is removal-i.e., disposition or disposal of the shredded waste. There are three removal systems now in use at various size reduction facilities in the United States. The waste can be:

a. Directly conveyed to the next operation in the solid waste management system; or

b. Loaded into transfer vehicles for bulk transport to the next operation; or

c. Placed in intermediate storage to await transfer and the next operation.

Direct conveyance of the shredded waste to the next operation is not a frequently used removal operation. In fact, it is generally only used when the next operation is landfill and the size reduction facility is located at the landfill site. Even then, it is not a common operation because of the capital investment required for long conveyor runs, and the fact that the waste will still have to be spread at the conveyor end. However, this procedure is used at Vancouver, Washington, and New Castle County, Delaware.

Loading the shredded waste into transfer vehicles for bulk transport to the next operation is a typical procedure, especially in landfill systems. This procedure offers a direct cost savings when the landfill is at a remote location. The size reduction facility can be placed at a convenient location within the collection system and serve as a shredding plant and a transfer station. Due to the reduced bulk of shredded waste and the large capacity of transfer vehicles, the cost of transporting the waste to the landfill can be significantly reduced. This type of system is in use at Milford, Connecticut; Madison, Wisconsin; Tacoma, Washington; and several other locations.

Placing the shredded waste in temporary storage prior to transfer to the next operation is currently the most common removal technique. The simple reason for this is the difficulty in synchronizing operations at the size reduction facility with the next operation in the system. Thus, a storage or buffer zone is needed. However, a major problem occurs in feeding the shredded waste out of the storage facility. The waste is easily compacted, does not readily flow, will bridge across openings and is, in general, difficult to handle in bulk.

Only two procedures for feeding waste from bulk storage are known to be in use. The first system is to extract the waste from the bottom of a storage tank with an auger or screw-feeder. The storage tank will have diverging sides to prevent bridging in the tank as material is removed from the bottom. The auger is horizontal and travels parallel to the bottom of the tank so that it "sweeps" the entire bottom surface of the tank. Examples of this type of installation are at St. Louis, Missouri; and Ecology, Inc., at Brooklyn, New York.

The other feeding system is a proprietary device marketed under the trade name "Atlas Feeding Systems." In this device, the waste is stored in an "open" pile inside a circular tank. Buckets that travel around the inside circumference of the tank scoop waste from the edge of the pile and dump it onto a moving conveyor. The device apparently works quite successfully, although it has not yet been installed in a large-scale municipal solid waste system.

D. Size and Power Requirements

The machine size and the power required for a solid waste shredder are determined by the size and nature of the input material, the processing rate (in tons per hour) desired, and the output particle size required. The output particle size determines the degree of size reduction required and the minimum theoretical energy required. The size and nature of the input material determines the minimum horsepower required to obtain at least minimum levels of performance without frequent jams or damage to the machine. The processing rate determines the physical size of the machine and the total horsepower required.

The following paragraphs present general guidelines for the selection of machine size and horsepower. The data presented in these paragraphs were developed from analysis of existing solid waste size reduction installations, contacts with machine manufacturers and users, and a review of the technical literature. The guidelines necessarily represent averages and are therefore believed to be conservative, i.e., use of the guidelines will yield specifications for a shredder that is more than adequate for the desired performance.

1. Input material: Determining the size and nature of the input material is the first step in selecting a properly sized shredder.

a. Categories of solid waste: A characteristic of solid waste is that it consists of a mixture with entire automobiles at one extreme and lightweight paper at the other. To simplify discussion of the problem, four categories of solid waste have evolved from common usage are in general use throughout the industry. The categories are shown in Table 2.

b. Municipal solid waste: Current per capita solid waste production in the United States is about 1 ton/year. Approximately 75% of this waste is light waste, about 20% is bulky waste, and about 5% is medium waste. (Heavy waste has been excluded because it represents a form of waste that is generally not collected and processed by government agencies and is not considered as municipal solid waste in the accepted understanding of the phrase.) This 75%-20%-5% mixture can be expected to "show up" at the input area of a solid waste size reduction operation that processes all municipal solid waste. This mixture will be referred to as combined municipal solid waste.

TABLE 2

SOLID WASTE CATEGORIES

<u>Solid Waste Category</u>	<u>Composition</u>
Light	Sorted packer truck wastes, such as-paper, cardboard, bottles, cans, garbage, and lawn trimmings.
Medium	Normal packer truck wastes, such as-the above plus small crating, small appliances, small furniture, bicycles, tree trimmings, and occasional auto tires.
Bulky	Oversize and bulky wastes of the above plus items such as-stoves, refrigerators, washers, dryers, doors, large furniture, springs, mattresses, tree limbs, and truck tires.
Heavy	Large and dense materials, all of the above plus items such as-demolition rubble, automobiles, logs, and stumps.

c. Minimum horsepower requirements: Experience has indicated that there is a minimum horsepower that is required to reliably and efficiently process municipal solid waste within a reasonable time and with a minimum of trouble and delay. The data shown in Table 3 represent the suggested minimum shredder horsepower for each waste category. These data are based on analysis of existing shredder operations.

TABLE 3

SUGGESTED MINIMUM SHREDDER HORSEPOWER

<u>Class of Waste</u>	<u>Minimum Horsepower</u>
Light	250
Medium	400
Combined	600
Bulky	800
Heavy	2,000

2. Particle size: The nominal or average particle size of the output material directly affects the power requirements of the shredder. The smaller the particle size, the larger the motor required for a given capacity or conversely, the smaller the capacity for a given motor size. Particle size is usually specified as a sieve size, for example a -5 in. size indicating that the product should pass through a sieve with 5 in. square openings. For many solid waste systems, particle size is relatively unimportant and a single specification is given. For example, a specification for shredded waste for a landfill might require a nominal -8 in. particle size. In another instance, such as boiler firing, particle size is quite important and is specified as some percentage of a nominal size and a maximum size for the remainder. For example, the specifications for the St. Louis, Missouri, installation which shreds waste for a fired boiler required 95% output with a nominal -1.5 in. size and 100% with a nominal -5.0 in. size.

Some limited data are available on the effects of particle size on power requirements. These data are shown in Figure 4 which plots unit input power (horsepower-hours per ton) vs particle size for the various categories of solid waste. For example, the data indicate that to obtain a minimal -6-in. particle size with the combined waste, a machine with a unit power of 17 to 18 hp-hr/ton is required. The data for Figure 4 were obtained from discussions with shredder users and manufacturers, from analysis of existing shredder installations, and from Ref. 2. These data are tentative and should not be considered as final until verified by test (see Chapter V).

One other consideration must be made when determining the power requirements for size reduction. The data indicate that power requirements increase exponentially as particle size decreases. Thus, for any given category of waste, there will be a particle size below which it becomes more economical to use two-stage size reduction (i.e., a primary and secondary shredder operated in series) than to use one large machine. Current practice in the industry indicates that for the combined bulky and medium waste, the minimum particle size economically feasible in a single stage reduction is in the range of 2 in. to 4 in. However, there is almost no available technical data (except manufacturers proprietary design data) on this subject and no standard procedures have

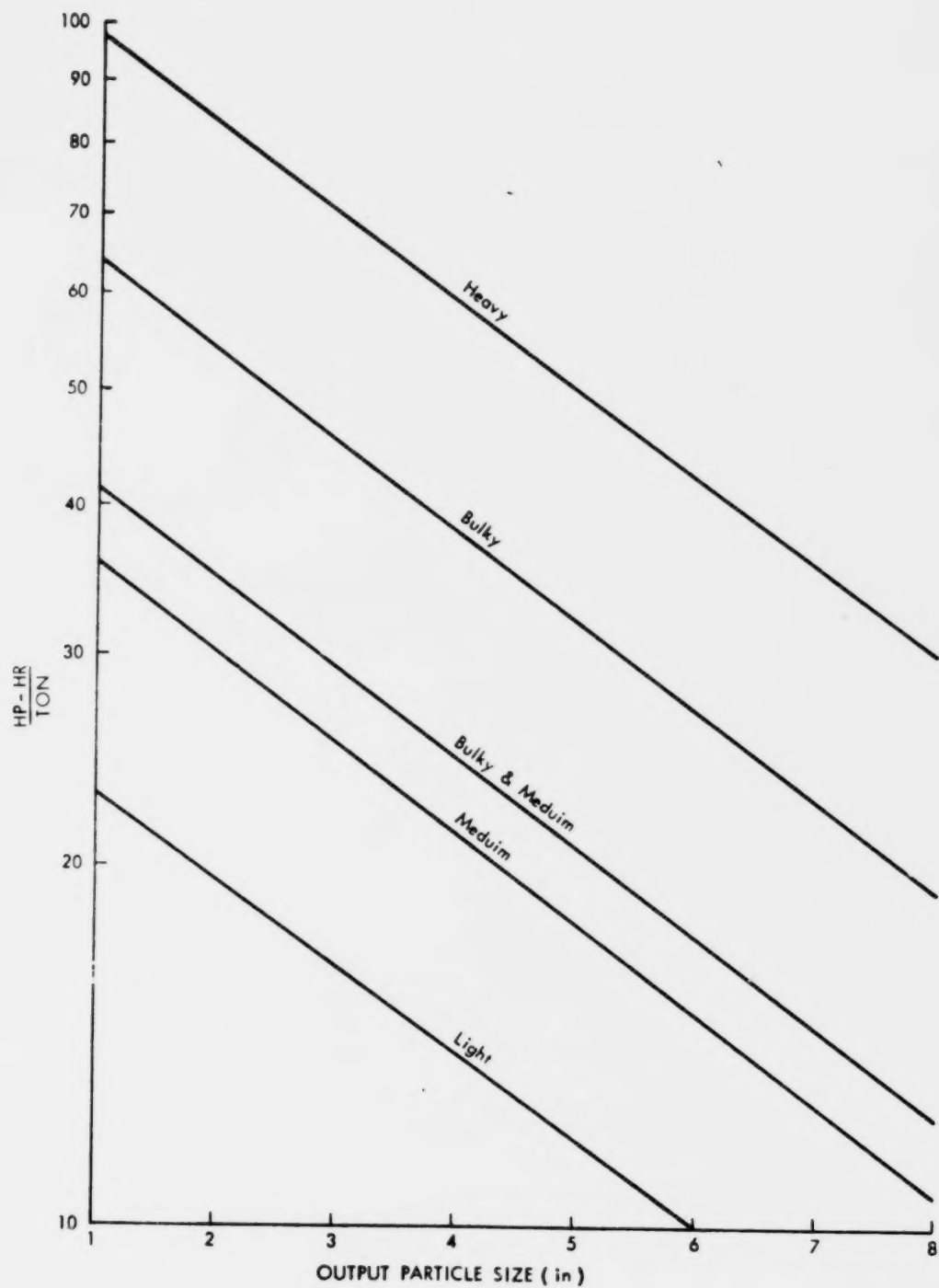


Figure 4 - Solid Waste Size Reduction Power Requirement

been developed. Each case must be examined individually, looking at such factors as power costs, wear factors, maintenance, labor costs, and capital investment.

3. Total throughput (tons per day and tons per hour): In addition to the category of waste, the particle size, and the power requirements, the total anticipated throughput must be known before the shredder can be sized. In many instances, this is a trivial question since the plant may be originally conceived and designed for a certain capacity in tons per day. This capacity is usually based upon some input parameter (i.e., the tons per day is known by previous collection data) or upon some output parameter (i.e., the size reduction plant is to supply shredded waste for a process that requires a given volume per day).

It is also necessary to establish what the nominal capacity of the machine will be in tons per hour. This requires an analysis of such factors as number of days per week, number of hours per day, and the normal working schedules of the collection system. Three major factors should be considered at this point-(1) Twenty-four hour operation is not practical; (2) There is a lag between collection of the waste and its delivery to the size reduction plant; and (3) There are practical limits on the capacity of a single processing line or facility.

Twenty-four hour operation is not feasible because the size reduction machines require constant and regular preventive maintenance. Hammers require frequent retipping, lubrication systems need refilling, mechanical adjustments must be made, etc. In some instances, where service application is severe (e.g., reduction to a small particle size in a single stage operation), one shift for maintenance is required for each shift of operation.

There is also a time lag between the collection of waste and its delivery to the size reduction facility. The packer trucks start each day empty as they do not normally store waste overnight. It is not uncommon, therefore, for the first packer truck to arrive at the size reduction facility with a load of waste 2 to 3 hr after the start of normal working hours. The last packer trucks may also arrive well before the close of normal working hours to allow time for return to their headquarters. Thus, all deliveries of waste to the size reduction facility would be made in a 5 to 6 hr period. It is common to schedule shredder operations beyond collection hours to completely process all of the day's input. However, due to health and safety hazards, unshredded waste is not usually left overnight for processing the next morning. Common practice has been to schedule the shredder for 6 to 8 hr operation a day, 5 days a week. However, most of these operations have been small plants processing 150 to 500 tons/day and, consequently, have smaller capital investments. As bigger and more expensive plants are designed and built (1,000-1,500 tons/day) the trend seems to be to a two-shift operation with 12-14 hr work periods each day.

General experience indicates that there is a practical limit to the capacity of a single size reduction operation. A capacity of 40 to 60 tons/hr begins to approach the limit for reasonable conveying and feeding systems. The volume of material represented by 40 to 60 tons/hr begins to present such severe logistical problems that efficient operation may require subdividing into two or more units if larger capacities are desired.

4. Total horsepower: After all of the above considerations on waste categories, particle size, power requirements, and machine capacity have been determined, total machine horsepower is simply the product of capacity in tons per hour and unit power required in horsepower hours per ton. For example, a 50-ton/hr machine processing waste with a unit power requirement of 20 hp-hr/ton would need a 1,000-hp motor.

Most knowledgeable persons in the field of solid waste size reduction believe that the 1,000-hp machine is an optimum size for processing solid waste. If total horsepower requirements exceeds 1,000 hp because of capacity, then as discussed above, consideration should be given to use of two or more processing lines. If total horsepower requirements exceed 1,000 hp due to particle size, then consideration should be given to use of two-stage size reduction or even three-stage operation in extreme applications.

5. Shredder selection nomograph: The data from Table 3 and Figure 4, and all of the above procedures, considerations and techniques for sizing and selecting a shredder have been combined into the nomograph shown in Figure 5. Use of the nomograph requires only knowledge of the category of solid waste to be processed, the output particle size desired, the capacity in tons per day and the nominal hours per day of operation. If the tons per day are not known they can be estimated by use of the right-hand side of the nomograph. These data represent the average ton per day per person of waste generated in the United States and should be used for planning and estimating only. Exact figures for the particular locality should be used for final specifications.

Use of the nomograph requires the following steps:

a. Estimate the shredding facility capacity by extending a line from the population to be served on the Population Graph, through the type of waste to be processed on the Waste Collected Graph, to the intersection of the 8-hr Throughput Graph.

b. Determine processing rate. If an 8 hr/day shift is anticipated, use the Tons per day intersection determined in step a above. If a 6-hr shift is anticipated, extend the intersection with the 8 hr/day horizontally to the 6 hr/day graph. Both the 8 hr/day and 6 hr/day graphs have the same vertical scale but are displaced horizontally to indicate the larger machine required for a 6 hr day.

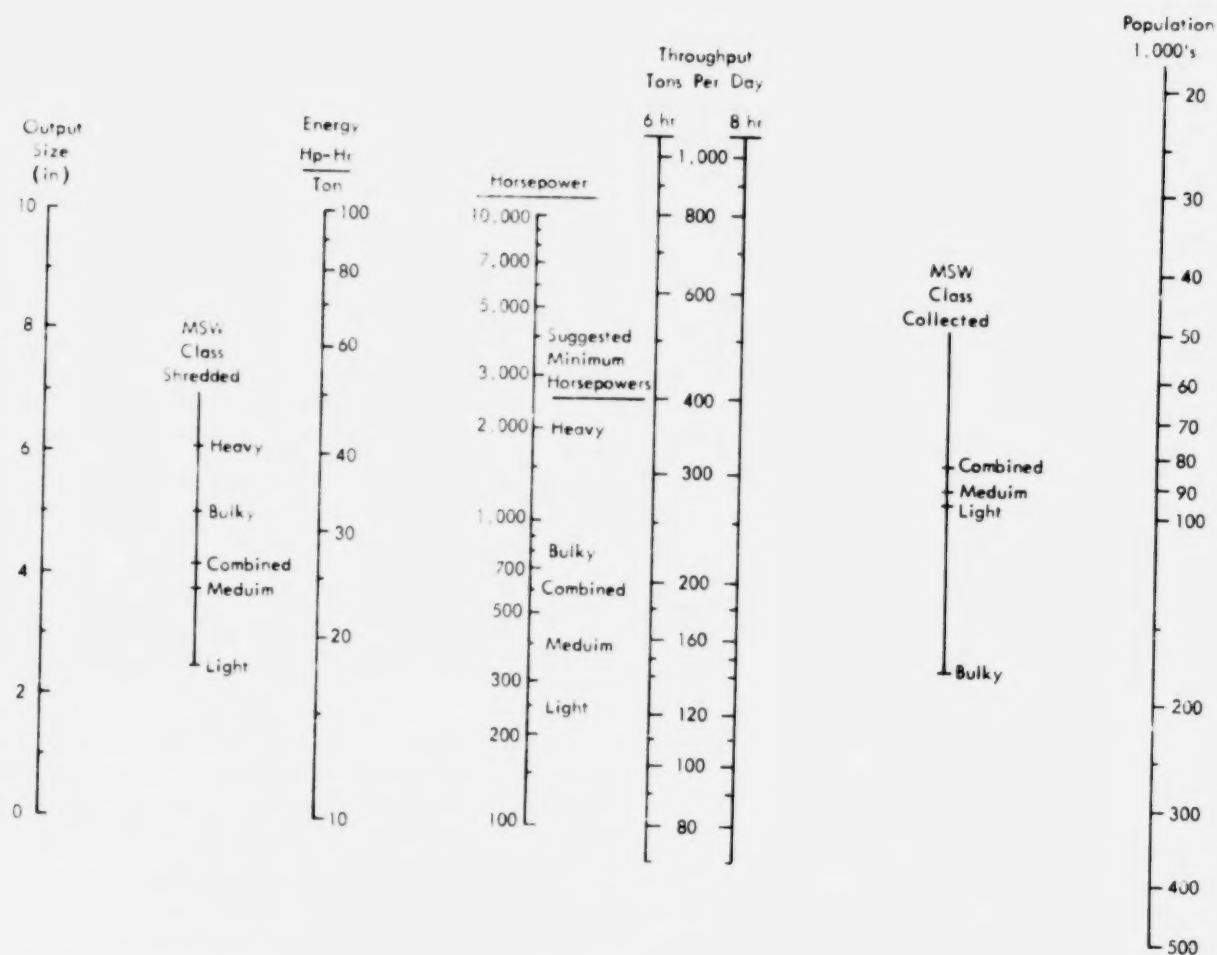


Figure 5 - Shredder Selection Nomograph

c. Estimate the unit power of the shredder by extending a line from the desired output particle size on the output size graph, through the type of waste to be processed on the Waste Shredded graph, to the intersection with the Energy graph.

d. Connect the intersection point on the Throughput graph with the intersection point on the Energy graph. Read machine size where the line crosses the Total Horsepower graph. Note if the total horsepower exceeds the recommended minimum horsepower for the type of waste to be processed. If not, use a larger machine.

Use of the nomograph will be demonstrated using as an example a community of 100,000 population planning to shred combined solid waste to a 5 in. particle size with 6 hr/day, 5 day/week.

a. At the right-hand side of the nomograph, extend a line from 100,000 on the population graph, through the combined waste point on the waste category graph, until it intersects the throughput 8 hr/day graph (380 tons/day.) Extend the intersection horizontally to the 6 hr/day throughput graph (also 380 tons/day.)

b. At the left-hand side of the nomograph extend a line from 5 in. on the particle size graph through the "combined" point on the waste category graph, until it intersects the unit power graph at 23 hp-hr/ton.

c. Connect the previously determined point on the 6 hr/day throughput graph with that on the unit power graph. Read total horsepower of 1,250 at the intersection of the horsepower graph.

d. Note that the total horsepower of 1,250 is larger than the 600 hp minimum recommended for combined solid waste.

CHAPTER IV

NUMERICAL RATING PROCEDURE

A. Introduction

This chapter presents a numerical rating system that has been developed for the comparison and evaluation of municipal solid waste size reduction equipment. The rating system is intended to be used by local government organizations that are responsible for the implementation of size reduction in a solid waste management system. The system is designed to provide a guide that will aid in selecting a specific size reduction machine from two or more candidates.

B. Numerical Procedures

The numerical rating system developed is the result of application of proprietary systematic numerical rating methods, which have been perfected at MRI. These methods were initially designed for use in highly specific applications in the metal fabrication field and have been developed and expanded for general application in recent years under the name Scaled Comparison Evaluation Techniques-SCET.

SCET is a remarkably effective method of collecting, articulating, and utilizing specific reference data--statistical information, performance data, specifications, and other so-called "hard" data--along with knowledgeable, but plainly subjective, human judgments (expressed in compatible form) to produce accurate indications of the comparative merits of candidate items being considered for selection under different sets of circumstances or applications.

In its elementary form, SCET converts information of heterogeneous variety into homogeneous "stuff of analysis"--zero to 10 numerical ratings--which are easily processed manually or by computer to reveal significant correlations and patterns. In all cases--regardless of the nature of the product, process or proposal being evaluated--a zero rating represents the "nadir" of evaluation, complete failure, a most unfavorable assessment. A five represents the horizon connotation (specifically described in every instance), the normal, the average, equal to typical competition. A 10 represents the "zenith" of evaluation, the best, the most favorable, clear industry leadership. Interim numbers are used to express shades of judgment upon these specifically described points of reference

Since these basic evaluation ratings seldom express the full measure of available information or knowledge about items being evaluated, companion scales are usually employed to provide ancillary

assessments or qualifications. In a typical SCET evaluation, for example, we may use a "confidence" rating ("What is the confidence that the evaluation is correct?") which ranges from zero as a "wild guess," to five as a "fair estimate," to 10 as an "absolute known fact." Most SCET evaluation models provide differential weights according to the credibility of the ratings, either as to the reliability of hard data or the relative qualifications of the evaluators.

A typical SCET evaluation begins with the identification of as many factors as possible that might influence the results, and then, the relative importance of these factors is determined. Next, a preliminary model (a carefully structured list) is developed which defines the zero, five and 10 levels--the "specific reference frames"--for all of the individual factors being evaluated. Proper design of the model and careful description of individual reference frames are the keys to accurate comparative evaluation, and a generous proportion of project time is spent here--learning what data to include and how to use the data so that answers can be fairly expressed as numerical ratings between zero and 10.

Next, trial rating sessions are conducted to test the relevance of the factors and the fairness and validity of evaluation reference scales, as they apply to performance data, specifications, and subjective opinions based upon actual operating experience. Criticisms of the preliminary model are openly invited during these trial rating sessions. All the knowledge gained in the preliminary phases is used to design a final model which addresses the many factors involved, properly balanced and weighted.

C. Development of the Numerical Rating System

Preliminary rating model: In the process of collecting data for the equipment inventory, numerous contacts were made with equipment manufacturers, size reduction plant operators, engineering consultants, and government agencies. All of these people were asked to list the factors they believed should be considered in selecting a piece of size reduction equipment. All persons were instructed to list all possible factors, no matter how minor, and to also include any special factors that may be unique to their experience. The main objective at this time was to develop as complete a list as possible for later analysis. No attempt was made at this time to evaluate or weigh the comments or to group them into an organized format.

The factors that were developed as a result of the above contacts were combined with those contributed by the project staff to form an initial list. This list included over 60 factors which were grouped into two distinct categories--Purchase Aspects and Operating Aspects. These factors are presented in Tables 4 and 5. The techniques of SCET were applied to the list by the program staff to determine the relative importance of each factor. As a result of the initial SCET analysis, the factors were reorganized into a new format containing five groups:

a. System Requirements Profile: The potential capability of the machine, as determined by analysis of the manufacturer's advertising, to meet or exceed the minimum performance requirements of the customer;

b. Suitability: The general capability of the machine to be integrated into the customers' solid waste management system;

c. Manufacturer's Reliability: The manufacturer's financial strength, relevant experience, and general reputation;

d. Specification Fulfillment: The known technical performance of the machine with regard to the technical specifications of the customer; and

e. Economy Index: The cost of purchasing, installing, and operating the machine.

TABLE 4

PURCHASE ASPECT FACTORS

Machine Weight	Special Installation Requirements
Machine Size	Output Particle Size
Rated Tons/Hour	Size Reduction Surfaces
Rated Tons/Shift	Weather Treatment
Batch Process	Contours Process
Input Location	Output Location
Unique Design Features	Control Systems
Horsepower	FOB Price
Delivery Cost	Installation Costs
Service Policy Availability	Type of Motor
Delivery Schedule	Performance Bond
Spare Parts Availability	Fire Control Systems
Manufacturers Reputation	Field Service
Existing Installations	Safety Features

TABLE 5

OPERATING ASPECT FACTORS

Actual Capacity (tons/hour)	Rotor Inertia
Unit Power (hp-hr/ton)	Weight
Maximum Output Particle Size	Effect of Moisture Control
Maximum Input Particle Size	Motor Machine Interface
Tons/Repair	Rejection of Nonprocessables
Backfire (ejection out the input)	Peak Power
All-Weather Operation	Power Cost
Labor Costs	Number of Personnel
Repair Skills Required	Operating Availability
Power Assist Devices	Lubrication Systems
Access for Maintenance	Complexity of Parts
Noise, Smoke or Odor	Operating "Headaches"

2. Major revision of the preliminary model: The techniques of SCET development were again applied to the preliminary model. Knowledgeable persons, including equipment manufacturers, users, and consultants were interviewed to gain their input into the rating procedure. The interviews were recorded for later review by the entire project staff. The recorded interviews were reviewed several times by the program staff and it was found that several significant trends in the interviews were apparent. These trends were:

a. Most of these knowledgeable persons—including equipment manufacturers and users—are of the firm opinion that only the hammermill can successfully and reliably process a material with the widely variable characteristics of municipal solid waste. Hammermills are the only type of solid waste size reduction equipment now being used in existing installations or being considered for future installations.

b. All hammermills currently being manufactured in the United States are either vertical shaft or horizontal shaft designs. Some persons contend that there are significant differences in the technical and economic performance of these two types of machines.

c. Most of these people believe that there will be little or no measurable difference in the performance of various machines of the same type (but from different manufacturers) that are being considered in response to the same set of performance specifications. For example, there will be no significant differences in the technical capabilities of three or four different horizontal shaft hammermills that have been proposed for a given application that is adequately described by proper performance specifications.

d. Variations in the cost of operating different size reduction machines cannot be fully attributed to differences in the

machine's performance. All machines of the same type (i.e., horizontal or vertical shaft) operate at about the same mechanical efficiency, use the same amount of power, and experience the same amount of wear per ton of throughput. Many of the cost differences can be directly attributed to the management policy of the facility and the accounting procedures used. Factors in this category include availability (working hours), service and maintenance practices, number of personnel, power costs, safety standards, etc. Although costs of these items can be measured, comparison of data from two different installations may not be valid because of different operational policies.

e. Any purchaser of a size reduction machine is interested in only three questions:

- (1) Is the manufacturer a reputable organization?
- (2) Is the machine adequate in size and power to do the job?
- (3) What does it cost to buy and operate the machine?

The five factors ("a" through "e") described above are considered major findings of this report. They represent a general opinion held by many knowledgeable people in the field of size reduction. These factors led the project staff to the conclusion that the Numerical Rating Procedure would be of most use if it helped the user answer the three questions in item "e". As a result, major revisions in the preliminary rating model were made. Several of the more specific technical factors were eliminated. Because of the many similarities in the design and performance of the various types of hammermills, emphasis was shifted from technical considerations to answering the question: "Is the manufacturer a reputable organization?" Technical considerations were reduced to rating the machine's size, power, and capacity against the available state-of-the-art design data and a test program was developed to improve the accuracy of the design data. Because of the variations in operating costs, economic considerations were limited to purchase cost and maintenance cost.

Thus, the final rating procedure consists of 18 factors arranged in three indexes that can be considered individually or collectively. The three indexes are the Manufacturers Index (factors that relate to the technical and financial qualifications of the manufacturer), the Technical Index (factors that relate to the technical performance of the machine), and the Economics Index (factors that relate to the cost of purchasing and operating the machine). The final model was again submitted to various knowledgeable persons for their opinions and comments. A list of the people who participated in the development of the numerical rating procedure is presented in Appendix I.

D. Summary of the Numerical Rating Procedure

The numerical rating procedure consists of three individual indexes that yield comparative ratings of two or more size reduction machines in three areas—a Manufacturer's Index, a Technical Index, and an Economic Index. Each index contains several ratings that consider specific aspects within the general topic. The complete text of the Numerical Rating Procedure for Comparative Evaluation of Solid Waste Size Reduction Equipment is presented in Appendix II. The following paragraphs present a brief review of the format and content of the system.

1. Section I - Manufacturer's Index: This index is designed to provide a relative rating of the technical and financial qualifications of the manufacturer of a size reduction machine. The rating will provide a measure of the capability of the manufacturer to design, build, install, and service a reliable piece of equipment. The index is composed of six individual ratings: Financial Strength, Shredder Experience, Existing Installations, Equipment Endorsements, Service Endorsements, and Industry Reputation.

2. Section II - Technical Index: This index is designed to provide a relative rating of the engineering expertise demonstrated in the design and fabrication of a size reduction machine. The rating will provide a direct measure of the capability of the machine to meet the required performance specifications of the customer. The index is composed of nine individual ratings: Horsepower, Input Limitations, Maintenance Intervals, Machine Weight, Rotor Inertia, Design Simplicity, Wear Adjustment, Power Assists, and Unprocessables Rejection.

3. Section III - Economic Index: This index is designed to provide a relative rating of the capital investment and operating expenses related to a size reduction machine. The rating will provide a measure of the effects on the net cost (in dollars per ton) of operating a size reduction facility that is directly incurred in the purchase and use of each machine. The Index is composed of three ratings: Installed Cost, Operating Costs, and Service Expectation.

E. Application of the Numerical Rating System

The numerical rating system is intended to be applied to two or more machines being considered for the same application. It is assumed that the user will have developed a comprehensive set of machine performance requirements including capacity (tons per hour), waste category, particle size, etc. In response to these performance specifications, he will receive bids from two or more manufacturers.

The system represents a carefully structured list of questions that should be answered for each machine under consideration. Each question is "answered" by rating, on a scale of zero to 10, the given aspect of the machine or its manufacturer. Some of the ratings can be determined objectively by the application of predetermined

guidelines. They require no interpretation or analysis on the part of the user. Most of the ratings, however, are subjective. They require that the user solicit value judgments from knowledgeable people.

Obtaining accurate value judgements is the most critical aspect of the rating procedure. It is essential that the user make sure each person understands the rating criteria and how to apply them. At the same time, the user should present the criteria fairly and honestly with no bias or attempts to slant the answers. It is also essential that the criteria be presented in the same manner to each person being questioned. Only in this way can accurate and comparable data be obtained.

By following certain established procedures, much of the guesswork inherent in such procedures can be eliminated. The following instructions present general guidelines that the user should observe when obtaining ratings for the subjective factors in the numerical rating procedure.

1. Develop a list of knowledgeable people who are qualified to participate in the rating procedure. In general, this list will consist of manufacturers, users, and consultants. Names of manufacturers and existing installations can be found in the equipment inventory (Ref. 1). Names of additional users or consultants can often be obtained from each contact. The user should also try to include different persons from the same source, for example, the plant manager, the plant engineer, and the plant operator at an existing facility.
2. Contact each person on the list and request their assistance. Explain to them who you are, what you are doing, and why you want their help. Assure them that all conversations are strictly confidential.
3. Use an individual worksheet similar to the one shown in Figure 6 to record the rating for each person. If possible, tape record all conversations for additional analysis.
4. Record all data on the data sheet yourself. Do not ask the person to fill out the rating sheet.
5. Ask each question individually. Thoroughly explain what the question is and what it is intended to measure. Explain the rating criteria and make sure the 0, 5, and 10 level criteria are understood.
6. For each question, ask the person to rate the machine on a scale of zero to 10 using the rating criteria presented with the question.

Machine Manufacturer _____

Make and Model No. _____

Source (Person Supplying Ratings) _____

Date _____ Evaluator _____

<u>Factor</u>	<u>Rating</u>	<u>Confidence Rating</u>
<u>Manufacturer's Index</u>		
1. Financial Strength	_____	_____
2. Shredder Experience	_____	_____
3. Existing Installations	_____	_____
4. Equipment Endorsements	_____	_____
5. Service Endorsements	_____	_____
6. Industry Reputation	_____	_____
<u>Technical Index</u>		
7. HP at Spec Tons/Hour	_____	_____
8. Input Limitations	_____	_____
9. Maintenance Intervals	_____	_____
10. Machine Weight	_____	_____
11. Rotor Inertia	_____	_____
12. Design Simplicity	_____	_____
13. Wear Adjustments	_____	_____
14. Power Assists	_____	_____
15. Unprocessable Rejection	_____	_____
<u>Economic Index</u>		
16. Installed Cost	_____	_____
17. Operating Cost, \$/Ton	_____	_____
18. Service Expectation	_____	_____

Figure 6 - Numerical Rating Procedure Individual Worksheet

7. Each person should answer every question, even those he may not be knowledgeable about. He should then be asked to evaluate the strength of his answer. A simple procedure is to ask him to rate his own answer (the confidence rating on Figure 6) from zero as a "wild guess," to 5 as a "fair estimate" to 10 as a known fact. These data can be used as weighting factors when averaging the ratings of several persons to the same question.

8. After completion of all questions, review the entire set of questions. Many persons may wish to make minor revisions of their ratings.

9. Try to obtain ratings from at least three persons for each question. Additional ratings should be sought if the initial three show widely differing values, or if the raters themselves have qualification ratings of less than 5.

10. Use a data sheet similar to the one shown in Figure 7 to determine the final rating for factors where two or more individual ratings are obtained. The rating and confidence rating from each evaluator for a factor are transferred from the individual worksheet (Figure 6) to the Factor Average worksheet (Figure 7). For each machine being evaluated, there will be 18 each of Figure 7 (i.e., one for each of the 18 factors).

11. Examine the pattern of ratings that are received. Disregard or de-emphasize the ratings of any one person if they are consistently out of line with the general trend.

F. Evaluation of the Results

1. Summary Sheet: The summary evaluation sheet for the Numerical Rating Procedure is shown in Figure 8. The 18 rating factors are listed on the left-hand side of the sheets. Spaces are provided to enter the individual ratings for each factor for up to eight machines. Each machine is identified by a code letter, and space for the code identification of the machine manufacturers is provided in the lower right-hand corner of the sheet. The ratings from the individual rating Factor Average sheets (Figure 7) should be transferred to this Summary Sheet for evaluation of the results. Additional spaces are provided on the Summary Sheet for entering individual index subtotals and the total ratings.

After the individual ratings for each machine are entered on the data sheet, the index subtotals are computed. The index subtotal for a machine is simply the arithmetic sum of all the individual ratings within the index.

2. Minimum qualifications: It is the opinion of the project staff that each machine should score above a certain minimum total for each index to be considered for further evaluation. Any machine that scores significantly below average on any factor represents a questionable investment and consideration should be given to eliminating it from further evaluation. The following minimum totals for each index are recommended: Manufacturer's Index-30 points of a possible 60; Technical Index-35 points of a possible 90; Economic Index-12 points of a possible 30. These minimums should be considered as guidelines and adjusted, if necessary, to fit each user's special needs. The purpose of the minimum's is to draw attention to a potential danger, not to arbitrarily eliminate any one machine.

3. Weighting factors: The Numerical Rating Procedure consists of 18 individual ratings grouped in three categories. The 18 ratings are not of equal importance and, further, their relative importance will vary from one situation to another. The user will have to determine the true importance of each rating as it applies to his situation. However, experience has indicated that a fair approximation can be obtained if each factor is treated as equal and a multiplier applied to the index subtotal. The recommended multipliers and their effect on the relative weight of the index are shown in Table 7. These rating factors tend to emphasize the Manufacturer's Index; however, it was the opinion of the project staff that a fair application of this procedure would indicate that the greatest difference will occur in the Manufacturer's Index, and therefore this index should carry a high weight.

TABLE 7

RELATIVE WEIGHT OF INDIVIDUAL INDEXES

<u>Index</u>	<u>Number of Ratings</u>	<u>Index Multiplier</u>	<u>Relative Weight</u>
Manufacturer	6	2	12
Technical	9	1	9
Economic	3	2	6
Total			27

4. Sample Rating: It will be helpful to make a sample evaluation to explain the rating system and how it can be used to greatest advantage. For example, it is assumed that a potential purchaser of a machine has developed an adequate set of performance specifications, requested bids of all eligible manufacturers and receives five bids. The user has then applied the numerical rating procedure and developed the basic ratings for each machine, entered them on the data Summary Sheet and calculated the index subtotals

Factor _____

Date _____
Evaluator _____

	<u>Source</u>	<u>Rating</u>	<u>Confidence</u>	<u>Total</u>
1.	_____	_____ X	_____	= _____
2.	_____	_____ X	_____	= _____
3.	_____	_____ X	_____	= _____
4.	_____	_____ X	_____	= _____
5.	_____	_____ X	_____	= _____
6.	_____	_____ X	_____	= _____
Total =				_____

$$\text{Average Rating} = \frac{\text{Total}}{N \times 10} = \text{_____}^*$$

where N = Number of sources

* Transfer this value to summary data sheet.

Figure 7 - Numerical Rating Procedure Individual Factor Average

MUNICIPAL SOLID WASTE SHREDDER EVALUATION RATING SHEET

Evaluator

Date

No.	Rating Factor	MACHINE				INDEX SUBTOTALS	Index Multipliers	TOTAL RATINGS
		A	B	C	D			
1.	Financial Strength	-	-	-	-	$\frac{30}{\text{MIN}} \times 2$ A B C D E F G H Manufacturer's Index	A B C D E F G H Machine Code Identification:	
2.	Shredder Experience	-	-	-	-			
3.	Existing Installations	-	-	-	-			
4.	Equipment Endorsements	-	-	-	-			
5.	Service Endorsements	-	-	-	-			
6.	Industry Reputation	-	-	-	-			
7.	HP at Spec Tons/Hour	-	-	-	-	$\frac{35}{\text{MIN}} \times 1$ A B C D E F G H Technical Index	A B C D E F G H Machine Code Identification:	
8.	Input Limitations	-	-	-	-			
9.	Maintenance Intervals	-	-	-	-			
10.	Machine Weight	-	-	-	-			
11.	Rotor Inertia	-	-	-	-			
12.	Design Simplicity	-	-	-	-			
13.	Wear Adjustment	-	-	-	-	$\frac{12}{\text{MIN}} \times 2$ A B C D E F G H Economic Index	A B C D E F G H Machine Code Identification:	
14.	Power Assists	-	-	-	-			
15.	Unprocessable Rejection	-	-	-	-			
16.	Installed Cost	-	-	-	-			
17.	Operating Cost, \$/Ton	-	-	-	-			
18.	Service Expectation	-	-	-	-			

* Minimum acceptable Index.

Figure 8 - Numerical Rating Procedure Data Summary Sheet

and total ratings. The example data are shown in Figure 9. The question now is, "What does this information reveal?"

Bidders A and B are marginal (2 and 0) in the aspect of financial strength. B has a dangerous lack of experience in manufacturing and selling the desired kind of equipment. A and B are deficient in service endorsements and reputation, a common penalty for lack of size. A tally of Manufacturer's Index ratings for A (24) and B (11) shows that both companies have fewer than the minimum number (30) of points recommended for further consideration. Unless there is some other reason to continue their evaluation, it may be wise to close their files at this juncture, and do not bother to evaluate them further. Even if all of their subsequent aspects were to be rated as 10's, it may be dangerous to deal with A and B on this contract.

Bidder C has no experience (0) in the municipal waste shredding field; and this weakness pulls its Manufacturer's Index down to the bare minimum (30 points) required for further consideration. Judging by its ratings for installed cost (8) and service expectation (10), it is probably a local firm—but the pattern of ratings in the Technical portion discloses unmistakably that the company does not make machinery rugged enough for waste. Unless there are very extraordinary overriding considerations, do not involve the community's basic solid waste processing problems in a local firm's research and development program.

In the presence of proposals from D (196 total points) and E (192), Bidder C (140) should be rejected.

Up to this point, the evaluation rating system has been used merely as a screening mechanism. It is more than that. Bidders D and E, at 196 and 192 total points, respectively, are for all practical purposes equally qualified. The evaluation system contains many plainly subjective ratings which are not accurate to within plus or minus 1 on a zero to 10 scale. Subjective evaluation simply does not deal in measurements more sensitive than that. Differences of 5% in the total ratings are probably not as significant as some of the differences in the patterns of aspect ratings.

Examine the differences between D's and E's aspect ratings, very carefully, with a view toward the municipality's particular needs:

Bidder E has done more municipal shredding; and since it is a tough pioneering field, this might explain its 8's (compared with D's 10's) in equipment endorsements and industry reputation. The company's 3 (vs 5) in horsepower at specification tons per hour and its 4 (vs 7) in input restrictions may simply reflect judgment which comes with the greater experience in processing municipal solid waste. The E unit is generally at a disadvantage in the technical

MUNICIPAL SOLID WASTE SHREDDER EVALUATION RATING SHEET

Evaluator Harold Donnelly

Date 7/17/73

No.	Rating Factor	BASIC RATINGS								INDEX SUBTOTALS	Index Multipliers	TOTAL RATINGS
		A	B	C	D	E	F	G	H			
1.	Financial Strength	2	0	5	7	9	--	--	--	30 MIN*	30 50 51 -- -- -- x 2 A B C D E F G H Manufacturer's Index	x 141 196 192 -- -- -- A B C D E F G H
2.	Shredder Experience	2	0	2	10	10	--	--	--			
3.	Existing Installations	3	1	0	5	9	--	--	--			
4.	Equipment Endorsements	5	6	7	10	8	--	--	--	35 MIN*	39 66 54 -- -- -- x 1 A B C D E F G H Technical Index	Code Identification: A Worldwide Shredder B Ajax Size Reduction C National Crusher D Jones and Amer E Shredders, Inc. F G H
5.	Service Endorsements	3	2	4	8	10	--	--	--			
6.	Industry Reputation	4	2	5	10	8	--	--	--			
7.	HP at Spec Tons/Hour	x	7	5	3	--	--	--	--	12 MIN*	x 21 15 18 -- -- -- x 2 A B C D E F G H Economic Index	
8.	Input Limitations	--	7	4	--	--	--	--	--			
9.	Maintenance Intervals	--	3	5	7	--	--	--	--			
10.	Machine Weight	--	2	7	6	--	--	--	--	35 MIN*	39 66 54 -- -- -- x 1 A B C D E F G H Technical Index	
11.	Rotor Inertia	--	2	8	5	--	--	--	--			
12.	Design Simplicity	--	9	7	5	--	--	--	--			
13.	Wear Adjustment	--	4	10	7	--	--	--	--	12 MIN*	x 21 15 18 -- -- -- x 2 A B C D E F G H Economic Index	
14.	Power Assists	--	6	8	9	--	--	--	--			
15.	Unprocessable Rejection	--	0	9	7	--	--	--	--			
16.	Installed Cost	--	8	5	5	--	--	--	--	12 MIN*	x 21 15 18 -- -- -- x 2 A B C D E F G H Economic Index	
17.	Operating Cost, \$/Ton	--	3	5	6	--	--	--	--			
18.	Service Expectation	--	10	5	7	--	--	--	--			

* Minimum acceptable Index.

group of aspects, except for slight edges in maintenance intervals and power assists. The economic aspects give a slight advantage to E. Which would you choose, D or E?

Probably either one would be a safe choice--so the decision might be swung by considerations which are subtle and beyond the scope of a formal evaluation. Our own preference would go to E because of its greater experience in municipal waste processing and its high service endorsements and service expectations.

Note also that the 3 in horsepower might merely be a statistical aberration due to C's rating of 7--and C has been rejected. It is possible that E would be 7 or 8 (and D a 9 or 10) on a different list of candidate shredders.

Regardless of which one is chosen, the pattern of ratings will continue to be a useful monitoring tool through the periods of purchase, installation and early operations. The ratings comprise a working roadmap of potential pitfalls in either case. If D is chosen, note the weakness in municipal waste experience--and immediately get on the phone to managers of present installations and find out about their problems and how they resolve them. Make probing inquiries about horsepower at specification performance levels and maintenance intervals. And, set in motion a continuing effort to improve the service situation and establish several key personal service contacts within the company.

If the choice is E, see what can be done to accommodate--or relieve--the input restrictions, and whether the low rating in the horsepower rating (3) is merely the result of engineering conservatism in designing surge capacity with a light rotor.

CHAPTER V

SIZE REDUCTION TECHNICAL AND ECONOMIC PERFORMANCE TEST PROGRAM

A. Introduction

This chapter presents a test program to develop accurate and impartial technical and economic performance data for size reduction of solid waste. The object of the test program is to verify the technical design data presented in Chapter III, Paragraph D, to replace it where inaccurate, and to develop net operating cost factors. Such data are needed to intelligently plan, design, and fabricate a size reduction facility. Limited technical performance data for shredding of solid waste are available, but the majority have been accumulated from different sources and under uncontrolled conditions. Such data are subject to question and should only be used to indicate trends. The operating cost data that are available have also been unreliable because the information has been generally supplied by facility operators and is subject to various "bookkeeping" practices. Accurate technical and economic data are known by private processors, but they consider such data proprietary and confidential and will not make it available. Therefore, there is an obvious need for accurate and impartial information that is fully available to all organizations or municipalities considering size reduction of solid waste.

B. Recommended Testing Facilities

The original concept of the test program was to have a field facility where individual machines could be thoroughly tested to accurately measure their technical and economic performance. Very early in the conduct of this study, it became apparent that individual testing of each machine by each manufacturer was neither feasible nor desirable. Such a concept was found to be costly, time consuming, cumbersome, and inefficient. The capital equipment investment alone was estimated to exceed \$2,000,000 and studies indicated that the support equipment, especially conveyors, would not be adaptable to all possible shredder designs. However, the most important fact was that the cost of a complete test on a single shredder was estimated to be approximately \$25,000. Since the purchase price of the machines is in the \$50,000 to \$100,000 range, it was believed that no manufacturer could afford to participate in the test program. Thus, need for an alternate test program was indicated.

As the program continued, one important conclusion about solid waste shredders developed and became a major factor in the formation of a test program. That conclusion, discussed in Chapter IV,

Paragraph C, was that all shredders of the same type and size would perform at about the same technical level when operated at equal conditions. This meant that for a given installation, similar shredders from different manufacturers would exhibit similar technical levels of performance. Thus, it should only be necessary to establish these performance levels once for each type of shredder. Fortunately, both privately and publicly owned or supported installations with different types and sizes of shredders are already in existence in the United States.

1. Public installations: In the process of preparing the equipment catalog, it was determined that many of the solid waste size reduction facilities were partially supported by public funds--either federal, local or state taxes. It would therefore appear that these sites would be logical choices as test program facilities. They are already in operation, with experienced personnel and full support equipment, and frequently are dependent on continued government funds. Further, many are demonstration grant projects studying the technology of size reduction and therefore already set up to perform experiments and tests. (However, some of these units are very small and may not be suitable for the test program.)

We are fully aware that the EPA cannot simply force these existing facilities to participate in a test program. We are also aware that legal and procedural difficulties may prevent some that would desire to participate from doing so. However, the use of those facilities is an economically acceptable procedure for developing the technical and economic data needed. We therefore recommend that the EPA determine what financial and legal arrangements will be required to conduct the test program presented in this chapter at selected solid waste size reduction facilities in the United States that are supported by public funds. After a determination of the arrangements and costs associated with this approach, it can be compared with the arrangements and costs required for the use of private facilities as discussed in the next section.

2. Private installations: Many of the larger manufacturers of size reduction equipment maintain test facilities. They have accumulated considerable data and operating experience in evaluating their own equipment and also the equipment of competitors. Those companies that do not maintain their own test facilities, often have a "captive" (wholly owned) processing installation or a cooperating private installation that they can use for testing and evaluation purposes. Thus, a second solution to the problem of generating technical and economic performance data would be to have the manufacturers conduct the test program at their own facilities at government expense with government supervision of testing procedures and data collection. This proposed approach represents the least difficult method of collecting data. However, manufacturers consider technical and economic performance data for their machines as proprietary and classified information and may, therefore, be unwilling to participate.

A thorough study of the market would be required to determine which manufacturers have test facilities and are willing to participate.

C. Summary of the Test Program

1. Program intent: The test program is designed to develop accurate technical and economic performance factors for solid waste size reduction equipment. The resultant technical data will also be used to verify the technical guidelines used as base-line data for the numerical rating procedure.

Technical performance is measured in terms of the capacity of the machine in tons per hour and net tons per day. Factors that affect capacity are: unit energy (horsepower-hours per ton), category of waste, particle size, feed rate, and moisture content. Size reduction machines are normally designed to reduce a given tonnage per hour of a given type of waste to a given particle size. The machine is then sized by determining the unit energy in horsepower-hours per ton and multiplying by the desired tons per hour to obtain total horsepower required. Therefore, to be useful, technical data should be presented as graphs showing unit energy vs particle size with moisture content and type of waste held constant. Additional graphs are needed to show the effects of variations in type of waste or moisture content.

Economic performance is measured in terms of the cost, in dollars per ton, of operating the size reduction facility. This cost figure normally includes amortization of capital investment, power costs, labor costs, and maintenance costs. The test procedure, however, cannot accurately evaluate amortization or labor costs. Both of these items depend more on the management policies of an operation than upon the mechanics of the machine. Therefore, the test procedure is only designed to measure power costs and maintenance costs. The factors that affect these costs are unit energy (horsepower-hours per ton), tons per scheduled repair and cost per scheduled repair. A scheduled repair is defined as a repair that is predictable and occurs at some repeatable interval, e.g., resurfacing or replacement of major wear surfaces.

D. Technical and Economic Performance Tests

1. Test programs: Two test programs have been developed—the recommended program and a minimum effort program. Either program can be conducted at public sites or at private sites. The individual tests to be conducted within each program are identical.

a. The recommended test program: The recommended test program consists of conducting complete individual performance tests and collecting data at five test facilities. The five types of facilities recommended are:

(1) An installation with a horizontal shaft hammermill and a large output particle size. Examples are San Diego, California, and Tacoma, Washington.

(2) An installation with a horizontal shaft hammermill and a small particle size. An example is St. Louis, Missouri.

(3) An installation with a large vertical shaft hammermill. Examples are Milford, Connecticut, and Vancouver, Washington.

(4) An installation with a small vertical shaft hammermill, an example is Madison, Wisconsin.

(5) An installation with two-stage reduction. Examples are New Castle County, Delaware, and Ecology, Inc., Brooklyn, New York.

The recommended program is estimated to require a 20-month performance period.

b. The minimum effort program: The minimum effort program consists of conducting complete individual tests at two test facilities—a large horizontal shaft hammermill installation and a large vertical shaft installation. The minimum effort program is designed to develop technical and economic performance data for solid waste size reduction machines typical of machines that would be used in a large volume municipal installation.

The minimum effort program is estimated to require an 8-1/2-month performance period.

2. Selection of test sites: Following are the desired criteria for the test sites to be used for performance of the test program:

a. The site should be an existing public or private solid waste reduction facility or an acceptable private test facility. The installation shall have adequate conveying systems to feed the shredder at desired feed rates.

b. The supply of solid waste shall be adequate to assure normal operation at or near design levels at all times during the test program.

c. The facility operator must give assurance of full cooperation.

d. All operating and maintenance personnel should have extensive experience with the equipment.

e. Suitable truck scales for measuring the weight of solid waste delivered by each truck, should be available.

f. Suitable test facilities are required at the site including a field office for storage of test equipment and data records, and utilities, including telephone, power, and sanitary facilities.

g. The site should be in a moderate climate location or testing should be conducted in fair weather seasons.

h. The site should be geographically close to commercial testing laboratories that can make moisture content and particle size measurements.

3. Controlled test procedures: Following is a general description of the proposed tests and the estimates of the time required to conduct each test. The complete text of the test procedures is presented in Appendix II. These estimates were prepared after careful consideration of the data desired and the equipment to be tested. However, there are several major variables that cannot be accurately determined until the sites have been selected and evaluated. For example, the support facilities and conveyor system must be sufficient to adequately serve the shredder during the test. Also, availability of suitable equipment and accessories is not positively known.

Test Procedure No. 1 - Technical Performance Tests

The technical performance test is designed to determine the unit energy required for size reduction of solid waste. The test consists of processing a measured quantity of waste under controlled conditions and measuring the processing time in hours and unit power in horsepower-hours per ton. The data are then reduced to horsepower-hours per ton for a type of waste, moisture content, and particle size. Tests will be conducted at different feed rates to determine if feed rate affects energy requirements or particle size. Three feed rates are recommended—at design capacity and at plus or minus 25% of design capacity (manufacturer's recommendations). The three tests should be conducted once a day for 2 weeks (10 working days) to provide two replications of the normal weekly variation in waste. It is estimated that the tests at one facility can be completed in 4 weeks using one test engineer and one test technician.

Test Procedure No. 2 - Economic Performance Tests

The economic performance test is designed to determine the unit cost in dollars per ton for power and maintenance of normal wear items. The test consists of accurately measuring and recording the weight of solid waste material processed under controlled conditions, the frequency of scheduled repairs, and the labor and materials required for each repair. The tests should be conducted for sufficient time to cover three normal maintenance periods. The data are then reduced to determine tons per required maintenance, labor and materials per repair and thus, dollars per ton for maintenance. It is estimated that the test can be completed at one facility in 4 weeks using one test technician.

E. Performance and Evaluation of Test Program

1. Contractor: An independent contractor should be selected to conduct the test program and evaluate the test data. The contractor should be impartial, with no vested interest or bias towards a particular brand or type of size reduction equipment. The contractor should have

an extensive background in the field of solid waste technology, particularly in the areas of design, operations, and analysis of size reduction of solid waste.

The specific background experience of the contractor should include:

- a. A working knowledge of the equipment and machinery normally found in a solid waste size reduction facility;
- b. Technical expertise in conducting field programs, collecting and analyzing field data, and issuing written reports;
- c. Working contacts with manufacturers of size reduction equipment;
- d. An experienced engineer to serve as program director, and adequate technical and administrative support staff; and
- e. A past history of satisfactory performance in government contracts.

There are numerous consultants and technical institutions that can respond to the above qualifications. The program can also be conducted in-house by the United States Environmental Protection Agency, Office of Solid Waste Management Programs. It is recommended that equipment manufacturers be specifically excluded from conducting the test program.

2. Test program staffing: The estimated staffing of the test program is shown in Table 8. The estimates are shown for both the recommended program and for the minimum effort program.

The program staff shall consist of a program director, test engineer, and test technician. The program director should be a senior staff engineer for the contractor. He should have a background in both field and management phases of experimental programs. He should have a thorough knowledge of solid waste processing and handling. The program director should be supported by at least one test engineer whose experience and background are similar to the program director.

The test engineer will be required to be at the test site full time during the technical performance tests. If tests at different sites are scheduled simultaneously, more than one test engineer will be required.

The test technician will be required at the test site full time to assist the test engineer during the technical performance tests. The test technician will also be at the site full time to conduct the economic performance test and report the data to the test engineer.

TABLE 8
ESTIMATED PROGRAM STAFFING

	Man-Months Effort	
	Recommended Program	Minimum Effort Program
<u>Program Planning</u>		
Project Director	0.5	0.3
Test Engineer	1.0	0.5
<u>Technical Performance Test</u>		
Project Director	1.5	0.6
Test Engineer	3.5	1.4
Test Technician	7.5	3.0
<u>Economic Performance Test</u>		
Project Director	1.0	0.4
Test Engineer	1.0	0.4
Test Technician	5.0	2.0
<u>Report Preparation</u>		
Project Director	0.75	0.50
Test Engineer	0.50	0.25
<u>Totals</u>		
Project Director	3.75	1.80
Test Engineer	6.00	2.55
Test Technician	12.50	5.00

3. Program schedule: The times required to complete the recommended and minimum effort test programs are 20 months and 8.5 months, respectively. These estimates are based on the assumption that tests at individual sites will be scheduled consecutively with a 1-month delay between each test. The scheduling is as follows:

	Time in Calendar Months	
	Recommended Program	Minimum Effort Program
Project Planning	3	1.5
Conduct Tests at Individual Sites	15	6
Report Preparation and Submittal	2	1
Total	20 months	8.5 months

These total times can be shortened considerably by performing simultaneous testing of two or more sites.

4. Program cost estimates: The estimated cost of conducting the test program is presented in Table 9. The program costs are developed based on the cost of an individual site test (five for the recommended program, two for the minimum effort program) with the project planning and report preparation time prorated.

TABLE 9

INDIVIDUAL TEST COST

Program Director	0.75 month at \$1,600 = \$1,200	
Test Engineer	1.20 months at 1,400 = 1,680	
Test Technician	2.5 months at 700 = 1,750	
Total		\$ 4,600
Overhead, Salary Related, and G&A at 270%		12,500
Travel, Five Round-Trips at \$150/Trip		750
Subsistence - 60 Days at \$30/Day		1,800
Test Equipment Rental		500
Testing Laboratory Services		500
Reproduction and Supplies		1,000
Total		\$ 21,150

TEST PROGRAM COSTS

Recommended Program	five tests at \$21,000	\$105,000
Minimum Effort Program	two tests at \$21,000	42,000

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The following paragraphs present a summary of the major conclusions of this program.

1. Size reduction of municipal solid waste is an emerging technology. There is, as yet, no assembled body of knowledge on the planning, design and fabrication of facilities and equipment, or on the economics of purchasing and operating a facility.
2. Size reduction of municipal solid waste is a rapidly growing technology. Most manufacturers firmly believe that sales of size reduction equipment for application in solid waste systems will significantly increase in the next 5 years.
3. The major application of size reduction in the near future will be in landfill disposal systems. Size reduction is especially suited to landfill operations because it increases landfill capacity, reduces odors, blowing, and strewing, eliminates voids and reduces vermin infestation, and eliminates the need for soil cover.
4. The long-term future of solid waste size reduction is in resource recovery system. Size reduction produces a uniform particle size, increases heterogeneity, and reduces the bulk of solid waste. All of these factors can increase the efficiency of many of the currently proposed resource recovery systems.
5. There are 10 basic types of size reduction machines and many of them can theoretically be used for size reduction of solid waste. However, only two types--the hammermill and the wet pulper--are considered practical.
6. Hammermills are the principal type of solid waste size reduction machines now being used or considered for future installations in the United States.
7. The wet pulper is not usually considered a primary machine for size reduction. Although one installation is in operation in the United States, most wet pulper installations now being studied or proposed also include a size reduction machine ahead of the pulper.

8. Hammermills are either vertical shaft or horizontal shaft type designs. There are distinct differences in their technical and economic performances.

9. Most knowledgeable persons believe that there will be no significant differences in the technical performance of similar machines of the same type made by various manufacturers.

10. Reliable technical performance data for hammermills used in solid waste size reduction are not available. Some equipment manufacturers possess limited data on the performance of their machines, but consider the data proprietary and confidential.

11. Economic performance data for hammermills used in solid waste size reduction are available but unreliable. The data are usually reported in dollars per ton of waste and do not identify the cost of individual factors, such as capital investment, amortization, power, operating costs, and maintenance cost. Variations in the data are often due to bookkeeping practices, management practices, and inaccuracies in data collection techniques.

B. Recommendations

The following paragraphs present recommendations for future EPA work related to size reduction of municipal solid waste.

1. An experimental test procedure should be conducted to develop reliable technical and economic performance data for size reduction of solid waste. Chapter V of this report presents a comprehensive description of a recommended test program, including detailed test procedures and cost estimates.

2. Public and private organizations planning solid waste size reduction facilities should be encouraged to use the numerical rating procedure presented in Chapter IV. Use of the procedure can guide the organizations in the selection of a reputable dealer and proper equipment.

3. There is a demonstrated need for a comprehensive state-of-the-art report on planning, designing, building, and operation of a solid waste size reduction facility. The report should include a thorough systems analysis of the facility and all of the individual components.

APPENDIX I

PERSONS INTERVIEWED CONCERNING THE NUMERICAL RATING PROCEDURE

R. W. Taylor
Joy Manufacturing
Denver, Colorado

Arsen Darnay
Resource Recovery Division
EPA
Washington, D.C.

Mr. Leonard Glascock
Prolerized Steel Corporation
Kansas City, Kansas

G. Wayne Sutterfield
Commissioner of Refuse
St. Louis, Missouri

H. J. Shelton and John Carnall
Gruendler Crusher and Pulverizer
St. Louis, Missouri

John Law and Don Johnson
Williams Patent Crusher and
Pulverizer
St. Louis, Missouri

John Dillon
French Oil Mill Company
Piqua, Ohio

Joe Baxter
Bill Herbert
Black-Clawson
Franklin, Ohio

Calvin Hempling
Stedman Foundry
Aurora, Indiana

Kenneth Lee
American Pulverizer and Crusher
St. Louis, Missouri

Ralph Zawacky
General Metals
Denver, Colorado

Henry Munde
EIDAL, Inc.
Albuquerque, New Mexico

John Schreck
Hammermills, Inc.
Cedar Rapids, Iowa

Ray Wender
Logemann Brothers Company
Milwaukee, Wisconsin

John Reinhardt and Gary Boley
Madison Landfill Product
Madison, Wisconsin

Terry Jones
Newell Manufacturing Company
San Antonio, Texas

Jim Barrett
San Diego Refuse Plant
San Diego, California

Dr. George Trezak, Consultant
University of California, Berkeley
Berkeley, California

Lorrie Leichner
Vancouver Sanitary Service
Vancouver, Washington

Albert Gould
Enterprise Company
Santa Ana, California

Arthur Sternoff
Sternoff Metals
Seattle, Washington

Paul Chenard
Commissioner of Refuse
Milford, Connecticut

Dr. Stephen Varro
Ecology, Inc.
Brooklyn, New York

D.A. Savage and F. Stelwagon
Pennsylvania Crusher Company
Broomall, Pennsylvania

Paul Dion
State of Connecticut
EPA
Hartford, Connecticut

Uldis Kairins
County Engineer
Wilmington, Delaware

John Burkert
Delaware Design & Engineering
Dover, Delaware

APPENDIX II

NUMERICAL RATING PROCEDURE FOR THE COMPARATIVE EVALUATION OF SOLID WASTE SIZE REDUCTION EQUIPMENT

The following pages contain the text for the numerical rating procedure discussed in Chapter IV. The procedure consists of 18 individual ratings grouped into three indexes—Manufacturer's Index, Technical Index and Economic Index.

I. Manufacturer's Index

This index of the numerical rating procedure is designed to provide a relative rating of the capability of the manufacturer to build and service a reliable piece of equipment. The index is composed of six individual ratings: Financial Strength, Shredder Experience, Existing Installations, Equipment Endorsements, Service Endorsements, and Industry Reputation.

Rating No. 1 - Financial Strength

The purchase cost of a size reduction machine of sufficient capacity for processing municipal solid waste is in the range of \$50,000-\$100,000. This figure is for the machine and motor only, and does not include the other capital equipment needed to develop a size reduction facility. For investments of this magnitude, it is essential that the equipment manufacturer have sufficient financial strength to promptly fill orders, meet delivery schedules, maintain a spare parts inventory, and provide adequate field service. In addition, most municipal waste processing machinery will be installed in large plants that involve considerable capital investment and long amortization periods. Thus, it is also essential that the manufacturer have a foreseeable future equal in length to the projected life of the machine. For these reasons, it is important to consider the financial strength and the credit position of a prospective source for a machine.

Rating scale: What is the Dun and Bradstreet capitalization and credit rating of the manufacturer?

<u>Rating</u>	<u>Criteria</u>
0	DD-1 (\$35-50K cap., high credit)
1	DC-1 (\$50-75K cap., high credit)
2	CC-1 (\$75-125K cap., high credit)
3	CB-2 (\$125-200K cap., good credit)
4	BB-2 (\$200-300K cap., good credit)
5	BA-2 (\$300-500K cap., good credit)
6	1A-3 (\$500-750K cap., fair credit)
7	2A-3 (\$750-1 mil. cap., fair credit)
8	3A-3 (\$1-10 mil. cap., fair credit)
9	4A-3 (\$10-50 mil. cap., fair credit)
10	5A-3 (Over \$50 mil. cap., fair credit)

Rating No.2 - Shredder Experience

This section of the Manufacturer's Index is designed to determine the manufacturer's past and present manufacturing experience relevant to size reduction equipment and especially to size reduction equipment for shredding municipal solid waste. This rating is one of two related ratings--this rating for experience in manufacturing and selling size reduction equipment and Rating No. 3 for the number of installations actually shredding municipal solid waste with the manufacturer's equipment. Both of these ratings have a direct bearing on the capability of the company to select, recommend, design and fabricate a reliable piece of equipment.

Advances in the state of the art of size reduction technology have not been historically a scientific effort. Most of the extension of the technology into new areas has been based on accumulated practical experience. Even though the sales of size reduction equipment are expected to increase due to the newly developed market in size reduction of solid waste, the increase will not be sufficient to support a comprehensive R&D program to develop a specific shredder design for solid waste. For this reason, it is anticipated that future advances in size reduction technology will continue to be of an experimental nature. Therefore, the years of relative experience of the manufacturer in the design, fabrication and sales of size reduction machinery and the number of equipment installations completed was considered an important factor in rating the machine.

Rating scale: How many years has the manufacturer been manufacturing and selling size reduction machinery?

<u>Rating</u>	<u>Criteria</u>
0	5 years or less
1	6 years
2	7 years
3	8 years
4	9 years
5	10 years
6	11 years
7	12 years
8	13 years
9	14 years
10	15 years or longer

Rating No. 3 - Existing Solid Waste Size Reduction Installations

As discussed in Rating No. 2 above, size reduction of solid waste is an emerging technology and experience is a major strength of a manufacturer. The more direct to the subject the manufacturer's experience is, the more advanced and reliable the equipment is apt to be. The most accurate measure of the manufacturer's direct experience in size reduction of solid waste is the number of existing installations using his size reduction equipment.

Rating scale: How many installations now in operation processing municipal solid waste are using the manufacturer's size reduction equipment?

<u>Rating</u>	<u>Criteria</u>
0	0
1	1
3	2
5	3
7	4
9	5
10	6 or more

Rating No. 4 - Equipment Endorsements

Rating No. 5 - Service Endorsements

Rating No. 6 - Industry Reputation

These ratings are designed to develop a relative measure of customer satisfaction with the manufacturer's products and service. It is not sufficient that the manufacturers have adequate experience if his customers are unhappy with his product.

Customer satisfaction has been divided into product endorsements and service endorsements because of the generally inadequate service organizations of many manufacturers. In many cases, operators have indicated that they cannot get parts, those that they do receive do not fit, and that technical assistance is often incompetent. This situation is not unusual for an emerging technology, but should improve rapidly as sales increase.

Industry reputation is designed to measure nontechnical aspects of customer satisfaction. Typical questions that this rating tries to measure are: "Is the company reliable?" "Are they easy to deal with?" "Do they fulfill all contractual obligations?" "Even if their machine is only adequate would you recommend them for other reasons?", etc.

Rating scales (Ratings Nos. 4 and 5): Are you satisfied with the manufacturer's machine (service)? Would you recommend it to others?

<u>Rating</u>	<u>Criteria</u>
0	Recent customers are generally unhappy
5	Normal mix of complaints and compliments
10	Customers enthusiastically endorse the product

Rating scale (Rating No. 6): How would you describe the business and technical reputation of the manufacturer?

<u>Rating</u>	<u>Criteria</u>
0	Poor - Worse in the business
5	Adequate
10	Best - Generally acknowledged as industry leader

II. Technical Index

This index of the numerical rating procedure is designed to provide a relative rating of the engineering expertise demonstrated in the design and fabrication of a size reduction machine. The rating will provide a measure of the capability of the machine to meet the required performance specifications of the customer. The index is composed of nine individual ratings.

Rating No. 7 - Power Requirements

This rating is designed to measure the capacity of the machine to meet required performance specifications of the customer. The base line for evaluation is the guideline data presented in Chapter III, Paragraph D. For example, if the customer's performance specifications call for 40 tons/hr of combined waste with an output particle size of 6 in., the guidelines indicate that 17.5 hp-hr/ton are required and thus a 700-hp motor. If the manufacturer recommends a motor from 550 to 850 hp (plus or minus 25% of 700) then the rating is 5.

The rating criterion have been established on both the plus or minus sides of recommended values because both too small a motor and too large a motor are undesirable. Too small a motor means the machine is undersized and will not give adequate performance at or near design operating conditions. This factor is critical and should be carefully evaluated. Too large a motor does provide excess capacity for surge operation, but represents unused capital investment. Individual users of this rating procedure, who are not strictly limited on capital, may wish to modify the criteria to prevent derating a machine that has excess power. This is accomplished by omitting the + in each of the rating criteria below.

Rating scale: How does the manufacturer's recommended power requirements, in horsepower-hours per ton and total horsepower, compare with the guideline data for the same performance requirements (tons per hour of a given category of waste reduced to a given particle size)?

<u>Rating</u>	<u>Criteria</u>
0	Greater than plus or minus 50% of guidelines
1	Within plus or minus 45% of guidelines
2	Within plus or minus 40% of guidelines
3	Within plus or minus 35% of guidelines
4	Within plus or minus 30% of guidelines
5	Within plus or minus 25% of guidelines
6	Within plus or minus 20% of guidelines
7	Within plus or minus 15% of guidelines
8	Within plus or minus 10% of guidelines
9	Within plus or minus 5% of guidelines
10	Equal to guidelines recommendations

Rating No. 8 - Input Restrictions

Any given category of waste will occasionally contain an item that is not a normal component of that category (for example, a hardened transmission gear in medium solid waste) or an item that cannot be efficiently processed in a hammermill (for example, fabrics). The criteria for this rating are based on the potential damage that these items can do to a machine and, consequently, the special handling or presorting of the waste the manufacturer requires. If the machine can be easily and severely damaged, then all input waste must be thoroughly inspected and sorted. If the machine will reject or pass through the occasional item with no damage, then no presorting or special handling will be required. In most instances, the true capabilities of the machine will be somewhere between the two extremes.

Rating scale: What are the machine manufacturer's recommended procedures for handling the occasional difficult item that can be expected to be present in any specified class of input material?

<u>Rating</u>	<u>Criteria</u>
0	Continuous special handling or extensive presorting required for difficult items
5	Can process almost all normal items without special handling
10	Can process all items without special handling

Rating No. 9 - Maintenance Intervals

The size reduction surfaces in any machine are subject to severe impact, abrasion, and wear. Maintenance of these items, either by resurfacing or by replacement, is a major factor in the operation of the machine. All manufacturers have developed what they believe to be the optimum combinations of hammer number, location, shape, weight, and material and have optimized other items, such as cutter bars, breaker bars, grates, housings, liners, etc. Some machines wear faster than others and some machines are more sensitive to wear than others. Each manufacturer will have a recommended procedure for replacement or repair of major wear items on a normal maintenance interval. This recommended interval will have an effect on the use and availability of the machines, and when converted to units of tons of waste per repair, will provide a measure of machine efficiency.

Rating scale: What is the manufacturer's recommended interval, in tons of waste, that his machine can process and still meet specified performance, before repair of major wear items is required?

<u>Rating</u>	<u>Criteria</u>
0	Less than 50% of average interval from bids submitted
5	Average interval
10	Greater than 150% of average interval

Rating No. 10 - Machine Weight

Weight is a common yardstick that is used to evaluate many machine tools. The total weight of a size reduction machine, excluding motor and transmission, is in general, a direct measure of the durability of the machine—the heavier the machine, the more durable it will be. Weight is especially important in large size reduction machines. These machines are essentially very simple machines that rely primarily on brute force to do their jobs. They need to be heavy, sturdy, and possess sufficient mass to withstand the abuse they must take.

Rating scale: How does the weight of the machine compare with the average weight of all machines being considered?

<u>Rating</u>	<u>Criteria</u>
0	Less than 75% of average
5	Average
10	More than 125% of average

Rating No. 11 - Rotor Inertia

Rotor inertia is a measure of the capability of a size reduction machine to do its job effectively. These machines rely primarily on the application of brute force, and it is the rotor that applies the force. The higher the rotor inertia, the less susceptible the machine is to jams, and the more effective it is in processing large bulky items, resulting in less potential damage to the motor.

Rating scale: How does the rotor inertia, in pounds-feet squared of the machine compare with the average rotor inertia of all machines being considered?

<u>Rating</u>	<u>Criteria</u>
0	Less than 75% of average
5	Average
10	More than 125% of average

Rating No. 12 - Design Simplicity

Almost all size reduction machines are very simple devices. They consist mainly of a rotor in a housing. This factor is designed to establish a relative rating of the simplicity of design for the machines being considered. No simple hard and fast rules are available. The user must rely on his own analysis. However, he should at least consider the following factors:

1. Access to major wear items for repair-access doors or partial disassembly.
2. Hammer attachment to rotor and ease of replacement or repair-individual hammer pins vs. common shaft.
3. Bearings and lubrication system-special design of off-the-shelf components, access for repair or replacement.
4. Motor coupling-direct drive, belt drive, or transmission.
5. Special features, such as power assist devices.

Rating scale: How does the simplicity of design of the machine compare to that of other machines being considered?

<u>Rating</u>	<u>Criteria</u>
0	Poor, complicated, many moving parts, poor access, etc.
5	Average
10	Exceptionally simple, best of the group

Rating No. 13 - Wear Adjustment

All size reduction machines are subject to severe wear during operation. As the size reduction surfaces wear away, internal clearances change and the output particle size may be affected. Most users of size reduction equipment consider devices for adjustment for wear as a desirable feature. Most of these devices currently available are external, i.e., adjustment can be made without opening the machine. This rating is designed to measure the capabilities of the machine for adjustment for wear.

Rating scale: Does the machine design provide for adjustment of major wear surfaces to compensate for machine wear?

<u>Rating</u>	<u>Criteria</u>
0	No wear take-up adjustment
5	Average
10	Fully adjustable up to sacrificial limits

Rating No. 14 - Power Assist Devices

Power assist devices constitute another special feature that is considered desirable by most users of size reduction equipment. Power assist devices include such items as hydraulic door openers, hammer pin extractors, and hydraulic power units for wear adjustment devices. This rating is designed to determine whether the basic machine design can include these devices.

Rating scale: How well does the machine design provide for the inclusion or addition of power assist devices without special modification or alterations to the machine?

<u>Rating</u>	<u>Criteria</u>
0	Such devices cannot be included or added
5	Such devices can be included or added, but are optional equipment
10	Such devices are included as standard equipment

Rating No. 15 - Rejection of Unprocessables

Any size reduction machine will eventually receive an item that it cannot reduce or process in a normal manner. This rating is designed to determine what will the machine do with this unprocessable item. To prevent damage to the machine, it is essential that the item be rejected in a safe manner or passed on through the machine. If the item remains in the machine, then either the machine will jam or will be damaged. Machines currently available on the market have a

variety of systems including metal traps, ballistic rejection devices, and discharge chutes. All of these devices have, in general, been inadequate to guarantee machine safety.

Rating scale: What provisions or devices to prevent damage does the machine have for handling unprocessable items that are introduced into the machine?

<u>Rating</u>	<u>Criteria</u>
0	None-machine must be stopped
5	Average-machine has a device that has potential of preventing damage
10	Rejects or passes all items with no machine damage

Rating No. 16 - Installed Cost

This rating is designed to establish a relative rating of the total costs for installation of the machine at the customer's facility. Installed cost is the sum of FOB price, shipping charges, delivery and setup charges, and any special installation charges. The rating is intended to measure the net cost for the machine, in dollars, that actually change hands; therefore, any special financing or other agreements should also be included in determining installed cost. The evaluator is cautioned to include like items in computing the cost of each machine.

Rating scale: What is the net cost for the machine installed at the customer's facility compared to the net cost of all machines submitted?

<u>Rating</u>	<u>Criteria</u>
0	Greater than 150% of average of all bids
5	Average costs
10	Less than 50% of average of all bids

Rating No. 17 - Operating Costs

This rating is designed to establish a relative measure of the net cost, in dollars per ton, of operating the machine. Net cost should include only power costs, costs for maintenance labor and materials, and repair parts cost. The user should assume that the operating labor and overhead costs will be equal for all machines, unless the manufacturer specifically recommends personnel other than those the customer plans to use. Further, if amortization costs are to be included, all machines should be depreciated on an equal basis.

Rating scale: What is the net cost, in dollars per ton, for operating the machine compared to the average of all bids submitted?

<u>Rating</u>	<u>Criteria</u>
0	Greater than 150% of average
5	Average
10	Less than 50% of average

Rating No. 18 - Service Expectation

This rating is intended to measure the effects of the manufacturer's service policies on the operation of the machine. These machines are subject to severe abuse and require constant service and maintenance. Many will be installed in facilities that cannot tolerate long downtime due to parts unavailability or poor service from the manufacturer, i.e., the solid waste input to the facility must be disposed of.

Rating scale: What is the local service expectation from the manufacturer?

<u>Rating</u>	<u>Criteria</u>
0	Poor, no local representative or parts
5	Average, no discernible difference among the bidders
10	Excellent, local service and parts, home office within 100 miles

APPENDIX III

TEST PROCEDURE NO. 1 TECHNICAL PERFORMANCE TEST

A. General

This test is designed to determine the unit power required for the size reduction of solid waste. The test consists of processing a measured sample of solid waste under controlled conditions and measuring the processing time and total power used. The data are then reduced to horsepower-hours per ton of waste.

The waste sample is selected and sorted to form a uniform sample of one category of waste. Moisture content and output particle size of the waste is determined from samples taken after size reduction.

The test procedure requires a total of 30 tests with one machine. Three tests per day shall be conducted for 2 weeks (five working days per week). The test procedure is scheduled for 2 weeks to provide two replications of the normal weekly variations in waste content. The daily tests shall be made at designed processing rate (in tons per hour), at 75% of design rate, and at 125% of design rate. The different processing rates are to determine if there is any effect on unit energy and output particle size. The content of all test waste samples shall be adjusted to be the same category of waste.

B. Test Facilities

1. Test site:

a. Receiving area, approximately 50 ft by 50 ft for collecting the test sample of solid waste. The area should be located close to the shredder.

b. Bucket-equipped hi-loader or other suitable equipment for placing the waste sample into the size reduction facility input device.

2. Instruments and tools:

a. Suitable shredder drive motor power measuring device. The device can be an amp-meter, a watt-meter, a watt-hour meter, or other comparable instruments. It is recommended that the instrument be equipped with an automatic recording paper graph or chart.

- b. One stopwatch.
- c. Handtools, such as rakes, hoes, yardsticks, etc.
- d. Three each, 1 cu ft capacity plastic sample bags.

3. Personnel:

- a. Test engineer: The test engineer shall plan the test, determine the material processing rate, select the waste sample, supervise the test, and record all test data.
- b. Test technician: The test technician shall feed the waste into the facility input device and maintain a continuous and uniform flow rate of waste into the shredder. The test technicians shall also collect the samples of shredded waste for subsequent analysis.
- c. Test operators: The operators shall work at the direction of the test technician to operate the size reduction facility during the test. The operators should be regular employees of the size reduction facility.

C. Test Procedure

1. Preparation:

- a. Collect a sample of solid waste sufficient to supply the shredder for 1 hr at the test processing rate.
- b. Sort the sample to remove any items not considered normal for the category of waste being processed.
- c. Thoroughly mix the waste with the hi-loader. Bulky items or segregated items should be uniformly distributed in the sample.
- d. Inspect the shredder and major wear surfaces. Replace or repair any missing, broken, or worn elements.
- e. Verify proper operation of the drive motor power measuring device.
- f. All conveying equipment and the shredder shall be operating properly.
- g. All safety devices, including conveyor and shredder motor interlock shall be inspected for proper operation.

2. Test operation:

- a. Start all conveyors and feeders and the shredder, and allow all units to come to normal operating conditions.
- b. Begin placing the waste into the shredder input device with the hi-loader.
- c. Verify that the depth of waste on the input conveyor is the proper depth to obtain the desired feed rate.
- d. Distribute the waste evenly over the input conveyor to assure uniform and continuous operation of the shredder. Manual distribution using handtools may be required.
- e. Start the stopwatch and the drive motor power measuring device when the first waste from the sample enters the shredder.
- f. Continue to operate the shredder and waste, feeding at a uniform rate, until all of the test sample has been processed. Record the time and the power readings.
- g. If any delays occur during the test, note the time and power reading at shutdown and restart.
- h. Obtain three 1 cu ft samples from the shredded test waste. One sample should be taken from waste processed early in the test, the second near the middle of the test, and the third late in the test.
- i. Have a commercial testing laboratory test the samples for average particle size (by use of a sieve) and moisture content (weight before and after heating). Measurements of the sample should be made within 24 hr after test completion.
- j. Record the following data on the test record sheet:
 1. Category of waste
 2. Sample weight in tons
 3. Processing time in hours
 4. Total power in amps, watts, or watt-hours

E. Data Reductions

1. Convert the power data from amps, watts, or watt-hours to horsepower.
2. Determine the processing rate in tons per hour by dividing weight in tons by time in hours.
3. Determine the unit power in horsepower-hours per ton by dividing the power in horsepower by the tons per hour.

4. The test particle size is determined as the numerical average of the particle size of the three samples. The test moisture content is determined as the numerical average of the moisture content of the three samples.

5. Enter the following data for each individual test on the test summary sheet:

- a. Waste category
- b. Processing rate
- c. Horsepower-hours per ton
- d. Particle size
- e. Moisture content

TEST PROCEDURE NO. 2
ECONOMIC PERFORMANCE TEST

A. General

This test is designed to determine the net cost, in dollars per ton, of power and machine wear for size reduction of municipal solid waste. The test consists of monitoring the amount of waste material processed through three normal repair intervals and accurately determining the cost of labor and materials for each repair. A normal repair is defined as a repair or replacement of a major wear item in the shredder that has been worn beyond normal operating limits. The data are then reduced to determine the tons per repair interval, the cost per repair, and the dollars per ton of repair.

The test procedure requires no special samples of waste, but is based on the usual waste processed at the site. If a private test facility is used, then packer truck materials from the local area shall be used. The waste shall be sorted and separated to conform to one of the five basic categories. Test conditions and facility operation shall, as closely as possible, duplicate the daily operations of a solid waste size reduction facility.

This test procedure is not economically feasible for application at facilities that have shredders with unusually long repair intervals (i.e., longer than 8-10 days). In such instances, the test procedure must be monitored by the facility operator with a minimum supervision. Because of the operator's concern with day-to-day problems, the accuracy and completeness of such data are questionable.

B. Test Procedure

This test procedure does not require any special facilities, instruments, or tools. Also, no special test methods or procedures are necessary. The test is performed by the test technician.

1. The test shall begin after the shredder has been repaired or rebuilt to an as-new condition. All broken, missing or worn major wear items-breaker bars, cutter bars, liners, etc.-shall be replaced or repaired.

2. The test technician shall observe the incoming waste and record the weight and type of all material processed by the shredder.

3. When the machine is shut down for maintenance, the technician shall inspect the machine and record the condition of all major repair items.

4. The test technician shall observe the maintenance procedure and record the following data:

a. Number of personnel and their labor category-i.e., foreman, welder, laborer, etc.

b. The number of hours each member of the maintenance crew actually participates in the maintenance work.

c. The type and amount of materials used in the maintenance work.

5. The above procedure (steps 1-4) shall be repeated three times.

C. Data Reduction

1. The ton per repair shall be the arithmetic average of the amount of material processed through the machine during each of the three intervals.

2. The cost of the labor shall be computed by using standard salary figures for the local geographic area.

3. The cost of materials shall be computed by using the manufacturer's advertised retail price.

4. The cost of a repair is the sum of the labor and materials cost.

5. The cost of maintenance in dollars per ton is determined from the average tons per repair and the cost per repair.

VOLUME II
INVENTORY OF SIZE-REDUCTION EQUIPMENT

CHAPTER I
INTRODUCTION

The purpose of this equipment inventory is to assemble the available technical and cost data on size reduction equipment in the processing of municipal solid wastes. (Size reduction is defined as operations which reduce the size of influent materials through division into two or more sub-units.) The data and narrative material included in this inventory are intended to be used as an aid in the selection of size reduction equipment. Use of the catalog represents the first step in the selection process--screening of available sources of size reduction equipment to determine those sources that can provide equipment of the proper type, capacity, and size for the intended application. The second step for a prospective purchaser is to contact the manufacturers and suppliers of size reduction equipment that are screened in the first step to solicit specific technical data and cost estimates.

The information contained in this inventory presents the state of the art in size reduction of municipal solid wastes. In many instances the technical data are very limited. This is an indication of the "newness" of the application of size reduction to solid wastes. There are only a few municipal solid waste processing installations in the United States that include size reduction of the waste. Many of these are now, or have been, partially funded by the EPA as demonstration projects. Almost all are pilot operations, handling small volumes and small percentages of the total solid wastes of the surrounding area.

The following sections of this inventory present a general background of size reduction equipment, a discussion of the sources of information for the inventory, selection guidelines based on the experience of operators of municipal solid waste size reduction equipment, and data sheets from each of the manufacturers and suppliers of size reduction equipment. A list of existing municipal solid waste size reduction installations is presented in Appendix I.

CHAPTER II
SIZE-REDUCTION EQUIPMENT*

Size reduction is the mechanical separation of bodies into smaller pieces. Size reduction of municipal solid waste is becoming of more interest because it facilitates handling, and permits more efficient separation and recovery processes. There are ten basic types of size reduction equipment generally available--crushers, cage disintegrators, shears, shredders, cutters and chippers, rasp mills, drum pulverizers, disk mills, wet pulpers, and hammer-mills. All except cage disintegrators, cutters, and disk mills have potential application in either primary or secondary municipal waste size reduction. However, only hammermills and wet pulpers are currently being used for municipal solid waste size reduction in the United States. The following paragraphs present brief descriptions for each of the above types of machines.

Crushers: Crushers are normally relatively slow-speed devices that apply compression forces to reduce the size of friable materials such as coal and rock. They are generally used in mines and quarries and their potential application in municipal solid waste is limited to size reduction of bulky items and construction rubble.

Four types of crushers are generally available: jaw, roll, gyrating, and impact (see Figure 1, p. 5). Only the impact type seems to have application for solid waste size reduction. Machine sizes range from 25 hp to over 2,000 hp in mining installations.

* Condensed from Recovery and Utilization of Municipal Solid Waste, U.S. Environmental Protection Agency, Solid Waste Office, SW-10c.

Cage disintegrators: Cage disintegrators (see Figure 2) use single or multiple high speed contra-rotating cages to fragment input material. Input is to the center cage and size reduction occurs as the material moves radially. The machine is usually only effective with brittle materials such as glass, and is used primarily in the chemical process industries where close control of output particle size is required. Cage disintegration does not appear to have any application to primary processing of municipal solid wastes. However, they could be used for secondary size reduction of separated friable materials in a resource recovery system.

Shears: Single-blade shears (see Figure 3) are a size reduction device whose application is limited to bulky items such as automobile bodies, lumber, and demolition wastes. They are most often found in scrap yards and similar operations. For processing of municipal wastes, they would be used for presizing of items too bulky to fit into the size reduction machine.

Cutters and chippers: Cutters and chippers are available in many configurations. Two basic types--the pierce and tear type and the cutting type (see Figure 4)--are of interest. The cutting type is the more widely used of the two, although both types are generally only used for size reduction of paper and cardboard. Both types are subject to excessive damage from unsorted refuse and do not appear suitable for municipal solid waste processing. Larger chippers, such as those used for reduction of brush and yard waste, would appear to have some application in solid waste, but they are generally of small capacity.

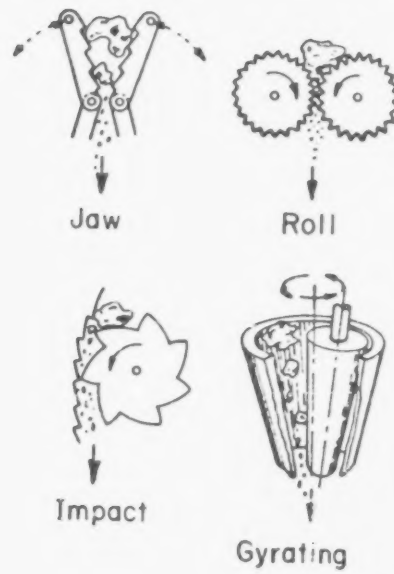


Figure 1 - Crushers

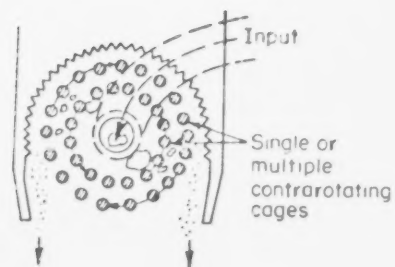
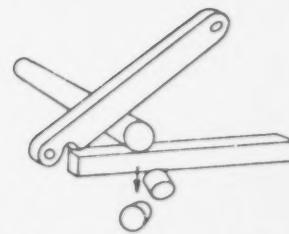


Figure 2 - Cage Disintegrators



Single alligator-type

Figure 3 - Shears

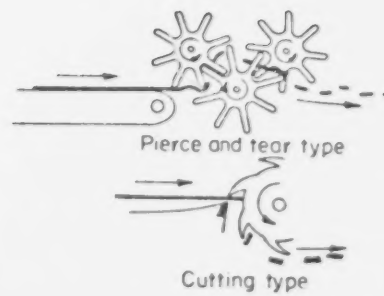


Figure 4 - Shredders, Cutters, and Chippers

Rasp mills: Rasp mills are large, slow-speed cylindrical machines, about 20 ft in diameter, used primarily in composting plants. The machine has a bottom grate with holes and rasping pins (see Figure 5). A large heavy rotor passes the waste over the pins and down through the holes. Bulky, non-reducible solid waste is rejected. Rasp mills appear to be suitable for size reduction of municipal solid waste and some are being used in Europe.

Drum pulverizers: A drum pulverizer is essentially a rasp mill with a rotating grate and a stationary arm (see Figure 6). The drum, or perforated grate, may be circular, octagonal, or hexagonal in shape. Some types of drum pulverizers may have moving arms or baffels. These machines are slow speed (up to 10 rpm) and may be a batch process operation and they can accept a wide range of input materials.

Disk mills: Disk mills operate by tearing material placed between two flat surfaces, one or both of which are rotating at high speed (see Figure 7). They are precise machines that are normally suited for pulpable materials and they are usually found in paper mills. Their major disadvantage is that input particle size must be small--less than 2 in.--and therefore would be suitable only for secondary reduction of municipal solid wastes.

Wet pulpers: A wet pulper is a type of vertical single disk mill that operates under water (see Figure 8). It reduces the size of input material by forming a water slurry (90% water, 10% solids), and forming a high-speed water vortex. The input material is suspended in the vortex and subject to repeated impact with stationary hardened impact bars of the pulper. Wet pulpers are best suited for pulpable and fibrous material; however, they can

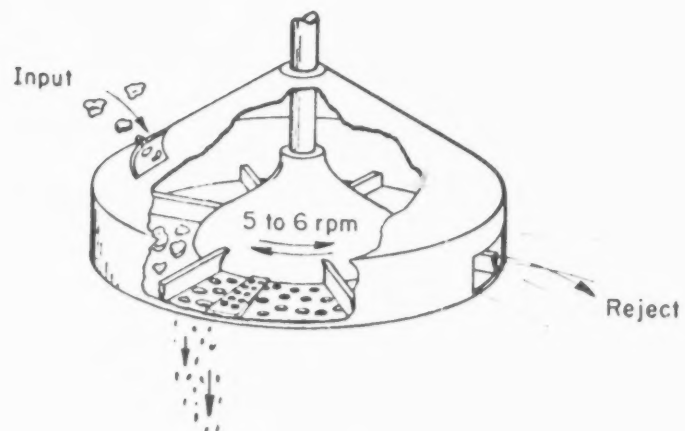


Figure 5 - Rasp Mills

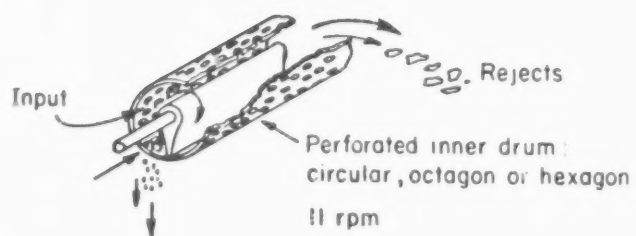


Figure 6 - Drum Pulverizers

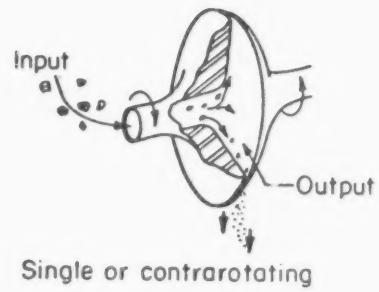


Figure 7 - Disk Mills

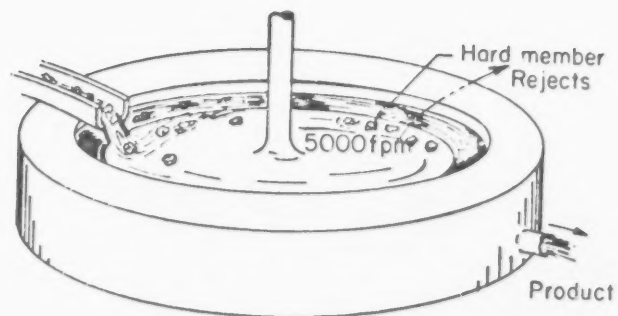


Figure 8 - Wet Pulper

accept a wide range of materials, including metals. Application to municipal solid waste processing is primarily in composting or fiber recovery operations.

Hammermills: Hammermills represent the largest percentage of municipal solid waste size reduction equipment. There are hammermills for all types of input materials, and machine sizes range from small laboratory models to huge machines capable of accepting entire automobile bodies. A hammermill consists of a center rotor with radius arms (hammers) protruding from the rotor circumference. The rotor is enclosed in a heavy duty housing. Some hammermills have stationary breaker plates or cutter bars mounted inside the housing. Input material is literally beat and torn to shreds by the hammers.

There are three basic variations of the hammermills--the swing-hammer type, the rigid-hammer type, and the grinder type. In the swing-hammer type, the hammers are pivoted on the rotor. Hammer designs vary from sharp choppers to rectangular blunt beaters. The latter is most often used for refuse size reduction. In grinder type hammermills, the hammers are replaced by rotating elements, usually star wheels, which grind up the input refuse by rolling it between the star wheels and the housing side walls.

Most hammermills have horizontal rotors with top feed and bottom discharge. Output particle size is controlled by the size of openings in a grate placed across the bottom. Material remains in the hammermill until it is reduced sufficiently to fall through the grate. A unique variation of the hammermill is the vertical rotor type. These machines may have a

decreasing cross-sectional area between the rotor and stationary housing so that progressive size reduction occurs as the material falls through the machine.

CHAPTER III
SOURCES OF INFORMATION

The names and addresses of manufacturers, users, and consultants for size reduction equipment were obtained from the following sources:

Thomas Register of American Manufacturers;

Environmental Protection Agency and Office of Solid Waste Management Publications;

Advertisements in technical and trade publications;

In-house knowledge and experience; and

Trade shows.

Information obtained from the above sources was used to compile the list of manufacturers of size reduction equipment presented in Appendix II. This list was screened to eliminate companies producing only machines with a capacity less than 4 tons/hr and the manufacturers of special purpose machines not intended for use with municipal solid waste. Requests for catalog data, technical data, and advertising literature were made to the remaining companies. Many of these companies were reluctant to submit any information other than that contained in their advertising (some companies do only custom design and have no specific catalog data; others were secretive about their product). Those that did supply data are listed in Table I.

The original list contained the names of 76 sources of equipment. Many of these companies were eliminated because their machines were too small, were not suited for processing of solid waste, were designed to process only

TABLE I
COMPANIES FURNISHING DATA FOR THE INVENTORY

	<u>Type of Contact</u>	<u>Included in Catalog</u>	<u>Comments</u>
American Pulverizer	P.V.	Yes	
Black-Clawson	P.V.	Yes	
Buffalo Hammer Mill	P.L.	Yes	
Denver Equipment	P.V.	No	Not for refuse
Eidal International	P.V.	Yes	
Enterprise	P.V.	Yes	
French Oil Mill	P.V.	No	No future sales for refuse
Gruendler Crusher	P.V.	Yes	
Hammermills, Inc.	P.V.	Yes	
Hazemag	P.L.	No	Custom design only
Heil	P.V.	Yes	
Jeffrey Manufacturing	P.L.	Yes	
Logemann Brothers	P.V.	No	Not for refuse
Newell	P.V.	No	Custom design only
Pennsylvania Crusher	P.L.	Yes	
Proler Steel	P.V.	No	Custom design only
Richards Shear	P.V.	No	Custom design only
Stedman Foundry	P.V.	Yes	
Williams	P.V.	Yes	

Notes: P.V. - Personal Visit.
P.L. - Phone and Letter.

specific types of solid wastes (i.e., commercial scrap, building rubble, etc.), or they did not intend to distribute their machines in the U.S. Of the remaining companies, only about a dozen have machines in operation processing municipal solid wastes. Because of this, very little technical data supported by operational experience are available on size reduction equipment. Manufacturers ratings are often established by intuition, by extrapolation of limited test data, or from data for other materials. Capital cost and operating expense data are often unreliable because many of the size reduction machines processing municipal solid wastes are part of a project that is receiving government funds or is operated by a government body which has captive maintenance and operating personnel. Funds for these personnel may not appear in the net cost figures for the project. Thus, the potential user should be aware that the cost data available, in general, are subject to question.

CHAPTER IV SELECTION GUIDES

Development of size reduction technology to process solid waste has been partially supported by the Office of Solid Waste Management of the Environmental Protection Agency. In the past 10 years, this office has partially or wholly supported many demonstration grants or pilot projects. These installations represent the principal source of practical experience in the operation of size reduction equipment for the processing of municipal waste. Discussions with personnel at these installations and review of government reports indicate that there are certain facets in the process of size reduction that are common to all installations. Some of these are discussed in the following paragraphs

Materials handling: Size reduction of solid waste is apparently within the capability of current state of the art of machines. Most experienced personnel agree that the major system problem is refuse handling equipment, not the size reduction machinery. Because of the size, weight, and power requirements of size reduction equipment, it is usually necessary that the machine be stationary and bring the solid waste material to the machine. Municipal solid waste is not an easy material to handle. Some of the characteristics that make it difficult to handle are:

Density: Prior to size reduction, municipal refuse has a low density, and large process areas are required for large tonnage inputs. After size reduction, the density may be increased and the shredded waste will compact easier than unshredded waste. Because refuse is subject to compaction

both before and after size reduction, it must be handled in special ways. It cannot be "pushed" down a chute or tube or it will compact, bridge, and jam the apparatus. Auger feeding is especially unsuitable.

Mixture: The waste material is a heterogeneous mixture of particles of variable size, weight, and physical properties. There are no distinct physical or mechanical properties that can be utilized to facilitate easy handling.

Abrasiveness: Municipal solid waste is a very abrasive material and machine wear is a major problem. The abrasiveness is due to many factors, including: (1) the waste contains large amounts of paper and paper products that are abrasive in themselves; and (2) the waste is a mixture of materials with widely different physical properties.

Flammability: The majority of municipal solid waste is organic and is easily ignited. Because of the large amounts of energy being expended to shred the waste, high temperatures and sparks cause frequent fires. Fire control systems are a necessary requirement in most installations.

Presorting: Some degree of presorting of the input prior to size reduction is required for almost all installations. No size reduction machinery (except the very large hammermills capable of processing entire cars) can accept and process all of the waste normally delivered by packer trucks. For the smaller machines, the bulky wastes and all heavy gage metal must be removed. For the larger machines, large heavy metal pieces must be removed and bulky items must be distributed. Presorting the input is a manual

operation normally performed by the operator controlling the input to the size reduction machine.

Feed control: Efficient operation of the size reduction facility requires that the machine be fed uniformly. Intermittent or variable feeding of the machine can produce severe motor overloads, machine jams, and even damage to the machine. However, uniform feed is the single most difficult operational factor to maintain. Due to ease of compaction, refuse cannot be fed by screws. Due to bridging and agglomeration, it will not feed from hoppers or chutes. Pneumatic feeds are only partially successful. In most instances the waste must be physically picked up and placed on an input conveyor or similar device at the desired rate. Several of the demonstration projects have used a procedure in which an operator transfers the waste from a receiving area to the input conveyor with a high loader, bulldozer, crane, or other types of earth moving equipment. The operator thus controls the input by the amount and kind of material he places on the input conveyor.

Type of machine: The hammermill is the most widely used machine for the size reduction of municipal solid waste. The hammermill has been in use in other industries for over 50 years and there are several reputable manufacturers. Thus, the hammermill is readily available in a wide range of sizes, and has an extensive background of use. The hammermill has many advantages, including:

1. Reasonable control over output particle size: Specification of grate sizes and hammer clearances allows a wide range of effluent particle

size from under 1 in. (with double pass through two machines) to over 10 in. Particle size is reproducible within acceptable limits.

2. Limited presort required: The hammermill can process most bulky items (such as lumber, rubber tires, and small appliances) that are in normal packer truck waste. Some presorting is required to remove heavy metal pieces, rugs, large appliances, etc., except for the very large machines.

3. Simple machine design: The hammermill is a very simple machine. It has few moving parts and can be serviced by operating personnel.

Horsepower: Total horsepower of a size reduction machine is an indicator of the tonnage throughput capacity of the machine. For example, a minimum horsepower, depending on the type of wastes to be processed, is required to obtain minimum levels of performance without frequent jams or damage to the machine. The minimum horsepower requirement for a given type of waste will vary with machine type, degree of size reduction and other variables. However, the following values are commonly used in the industry as general guidelines for selecting a machine for a given application.

1. 250 hp - Light wastes--paper, cardboard, bottles, cans, garbage and lawn trimmings.

2. 600 hp - Normal packer truck wastes--including small appliances, some pieces of furniture, lumber and small commercial scrap, bicycles, auto tires, and tree trimmings.

3. 1,000 hp - Bulky wastes--large appliances, bed springs, mattresses and rugs, larger tires, tree brush, larger pieces of lumber.

4. 2,000 hp - Heavy wastes--automobiles (without engines), demolition rubble, tree trunks.

5. 3,000 hp - Entire automobiles (with engines), scrap metal.

In addition to the total horsepower of a given machine, the horsepower-hour per ton is another indicator of machine performance.

A horsepower-hour per ton rating is obtained by dividing the total horsepower of the main driver by the machine throughput capacity in tons per hour. For example, a machine with 1,000 hp motor and a rated capacity of 50 ton/hr of municipal refuse has a horsepower-hour per ton rating of 20. Discussions with operators of municipal refuse plants, EPA demonstration grants, and private refuse processors have indicated that the horsepower-hour per ton required to process municipal solid waste may be independent of machine type or manufacturer. Fifteen horsepower-hour per ton is generally considered the minimum rating and requires presorting to remove bulky items and close control of feed rates to prevent jamming, especially for small machines, i.e., less than 1,000 hp. Twenty-five horsepower-hour per ton is an average figure for general municipal refuse and provides the operator with the ability to handle moderately variable feed rates and occasional bulky items (such as tree limbs and large appliances) without stopping or jamming the machine. Thirty horsepower-hour per ton is a minimum value for continuous processing of heavy items such as automobiles, building rubble and heavy metal items.

Machine tool wear: Due to the abrasive nature of municipal solid waste, wear in a size reduction machine is a major operating expense. All

types of size reduction machines are subject to this wear. The major areas of wear are the cutting surfaces that actually perform the size reduction (for example, the hammers in a hammermill). Repair of worn areas is done by resurfacing or by replacement, with resurfacing as the more common method. Repair intervals vary with individual machines and with types of machines. However, preliminary analysis of existing plant procedures indicates that tool repair will be required after 1,000 to 2,500 tons of waste processed for the smaller machines (i.e., 500 to 1,000 hp), and after 2,000 to 5,000 tons for the larger machines (i.e., 1,500 to 3,000 hp).

Machine specifications: The size reduction machine is only one component of a municipal solid waste processing system. The system will include in most instances, the following components:

1. Receiving and holding - An area or device for accepting refuse from the primary collection or transfer system.
2. Refuse feed - A manual or mechanical method of placing the refuse on the size reduction unit input conveyor at a controlled rate.
3. Shredder input - A conveyor device to transfer the refuse into the shredder.
4. Size reduction.
5. Refuse output - A conveyor device to transfer the refuse away from the size reduction machine.
6. Discharge - An area or device that accepts the shredded refuse for subsequent processing or disposal.

Because of the large number of possible installations and the variation in the composition of solid wastes, manufacturers do not produce a "line" of off-the-shelf size reduction machines. Instead, they have a series of basic machine designs which can be "tailored" to fit a specific job. For this reason equipment specifications must be well defined in order to receive competitive bids. As a minimum, the specification should include the following information:

1. A description of the material to be processed, including maximum input particle size and any allowable presorting to prevent potentially damaging material from entering the shredder.
2. The minimum throughput rate desired in tons per hour and tons per day or shift.
3. The particle size of output required.
4. The main drive motor size and type (i.e., electrical, diesel, etc.), and peak power available for the motor.
5. The motor controls, if desired, including automatic and manual shut-offs, recording power meters, and overload protection.
6. A fire control system, if desired.
7. The type of input, including size and location--i.e., top loading conveyor or side loading feed chute.
8. Type of output, including size and location.
9. Machine installation requirement--i.e., indoors or outdoors, foundation size and type, and vibration limitations.

CHAPTER V
MANUFACTURERS' DATA SHEETS

This section contains brief descriptions of size reduction equipment manufacturing companies and catalog data on their equipment. Inclusion or exclusion of any manufacturer does not indicate endorsement or lack of endorsement by the EPA, but rather a willingness of the manufacturer to supply information to the project. Wherever possible, capacity in tons per hour has been included. These ratings have been supplied by the manufacturer.

American Pulverizer Company
1249 Macklind Avenue
St. Louis, Missouri

Machine type: Hammermill

American Pulverizer Company has been in business for over 60 years. Their principal products are size reduction machinery and related equipment such as conveyors, blow pipe, and cyclone separators. Their size reduction machines are the hammermill type and are generally special purpose machines--i.e., automobile, aluminum can, tin can, paperboard and corrugated cardboard, scrap wood and glass shredders, and metal trimming crushers. The company advertising literature describes two types of hammermills designed for refuse and garbage shredding, although no model numbers, dimensions, or technical data are presented. They do not report any existing installations with their machines processing municipal solid wastes. However, they have numerous installations with machines processing paper and corrugated refuse and scrap.

Their hammermills are of horizontal rotor design with top input opening and bottom discharge. The company prefers to do a "turn-key" job providing all necessary components including the hammermill, conveyors, separators, and air pollution control equipment. The technical data shown on the attached data sheet were obtained from company literature and discussion with company personnel.

AMERICAN PULVERIZER COMPANY, ST. LOUIS, MISSOURI

MODEL NO. OR SIZE	HORSEPOWER*	CAPACITY* (TPH)	SPEED (rpm)	FEED OPENING (in.)	DIMENSIONS (in.)			WEIGHT (lb)	FEED METHOD	CAPITAL COST
					LENGTH	WIDTH	HEIGHT			
WS-16				21 x 18	59	60	38	7,200	Top	
WS-22				21 x 23	59	66	38	8,000		
WS-28				21 x 29	59	72	38	8,800		
WS-34				21 x 34	59	77	38	9,800		
WS-40				21 x 40	59	82	38	11,000		
2400				31 x 37	72	76	49	14,000		
3800				31 x 49	72	88	49	17,000		
4200				31 x 55	72	94	49	19,000		
4800				31 x 61	72	100	49	22,000		
48-50				50 x 54	102	117	73	40,000		
48-60				50 x 64	102	127	73	46,000		
48-80				50 x 84	102	147	73	69,000		
48-90				50 x 94	102	157	73	83,000		
60-50				48 x 52	103	120	90	63,000		
60-60				48 x 62	103	130	90	70,000		
60-80				48 x 82	103	150	90	90,000		
60-90				48 x 92	103	160	90	105,000		
72-60				68 x 65	135	170	123	170,000		
72-72				68 x 76	135	182	123	190,000		
72-84				68 x 88	135	194	123	210,000		
72-96				68 x 100	135	206	123	235,000		
96-30				84 x 82	172	188	146	260,000		
96-90				84 x 92	172	198	146	295,000		
96-120				84 x 122	172	228	146	350,000		

* Throughput material for horsepower and capacity listed.

Automobile and scrap shredders.

AMERICAN PULVERIZER COMPANY, ST. LOUIS, MISSOURI

MODEL NO. OR SIZE	HORSEPOWER*	CAPACITY* (TPH)	SPEED (rpm)	FEED OPENING (in.)	DIMENSIONS (in.)		WEIGHT (lb)	FEED METHOD	CAPITAL COST
					LENGTH	WIDTH			
CS 330	75	3-4	600	45 x 30			12,000	Top ↓	
CS 350	100	6-8	600	45 x 50			17,000		
CS 361	125	8-10	600	45 x 62			20,000		
CS 370	150	10-12	600	45 x 72			22,000		
CS 380	200	12-14	600	45 x 82			25,000		
CS 390	250	14-16	600	45 x 92			28,000		

* Throughput material for horsepower and capacity listed.

Paper and corrugated material.

Black-Clawson Company
Shartle-Pandia Division
Middletown, Ohio 45042

Machine type: Wet pulper

The Black-Clawson Company is a worldwide organization supplying mechanical equipment for the wood, pulp and paper, paperboard, chemicals, metal products, rubber, and plastics segment of the chemical processing industry. The company manufactures machinery and equipment systems and provides research and development services and technical guidance. The principal products of their Shartle-Pandia Division include digesters, reactors, feeders, conveyors, filtration equipment, mixers and blenders.

The Black-Clawson Company does not have a line of size reduction equipment, as such. They are manufacturers of pulping equipment and custom design installations for processing solid waste. Black-Clawson has developed a solid waste disposal system called Hydrosposal and Fiberclaim. They are total systems designed to recover fibers, glass and metals, and produce an inert, nonputrescible residue. The company has a pilot plant operation at Franklin, Ohio. This plant is an EPA Demonstration Project for recovery of fibers and ferrous materials. The plant also separates glass and nonferrous metals. All recovered fibers are sold to a local paper company. Combustible residues are burned in a fluid bed reactor. All normal packer truck material (except auto tires) can be handled by the system. The pilot plant has a capacity of 6 ton/hr.

Buffalo Hammer Mill Corporation
1245 McKinley Parkway
Buffalo, New York 14218

Machine type: Hammermill

Buffalo Hammer Mill Company makes a series of small hammermills with their largest unit having a 300-hp drive motor. These mills are generally intended for use in commercial applications where they are processing specific types of materials. The units are top-fed bottom-discharge and are welded one-piece construction. They make special mills (i.e., stainless steel) and can provide a wide range of materials. They do not have any machines in operation processing municipal solid waste. The tonnage throughput values shown on the data sheets are not for municipal refuse but were demonstrated for much denser materials such as rock, etc. They do not recommend processing metals, rubber tires, or tough plastics with their machines.

BUFFALO HAMMER MILL COMPANY, BUFFALO, NEW YORK

MODEL NO. OR SIZE	HORSEPOWER*	CAPACITY* (TPH)	SPEED (rpm)	FEED OPENING (in.)	DIMENSIONS (in.)			WEIGHT (lb)	FEED METHOD	CAPITAL COST
					LENGTH	WIDTH	HEIGHT			
W-4-L	1/2 - 2	1/2 - 2	8,000	4	12	20			Top ↓	
W-6-L	1/2 - 3	1/2	8,000	6	14	20				
W-8-L	5 - 20	1	3,600	8	27	30				
W-12-L	15 - 50	5	3,600	12	30	30				
W-16-L	20 - 60	8	3,600	16	40	38				
W-20-L	25 - 75	15	3,000	20	43	38				
W-25-L	25 - 100	20	2,900	25	48	38				
W-30-L	50 - 150	30	1,800	30	50	54				
W-36-L	60 - 150	40	1,800	36	66	54				
W-40-L	75 - 200	60	1,200	40	72	60				
W-50-L	75 - 300	80	1,000	50	98	72				
W-60-L	100 - 300	100	900	60	108	80				

* Throughput material for horsepower and capacity listed.

Material not specified--however, capacities are not for solid waste, but much heavier materials.

Eidal International Corporation
(A Subsidiary of Southwest Factories, Inc.)
245 Woodward Road, S.E.
Albuquerque, New Mexico 87103

Machine type: Vertical shaft grinder-type hammermill

The Eidal Corporation has been associated with heavy equipment design and manufacturing for many years. They introduced their line of vertical shaft shredders in 1965. The company manufactures four basic machines ranging from a 100-hp "Mini-Mill" to a 2,000-hp "Brute." As shown on the data sheet, they have several installations where their machines are processing municipal solid refuse. The machines are top-loading, vertical-feed with bottom horizontal discharge. Material entering the machine flows through it by gravity and is progressively reduced in size until it reaches the output. Because the size reduction process is progressive, bulky items can be fed into the machine without presorting. The model 1000 is the Eidal unit recommended for general municipal refuse. User experience indicates that these machines may have a very low hammer or grinder wear cost per ton of waste.

EIDAL INTERNATIONAL CORPORATION, ALBUQUERQUE, NEW MEXICO

MODEL NO. OR SIZE	HORSEPOWER*	CAPACITY* (TPH)	SPEED (rpm)	FEED OPENING (in.)	DIMENSIONS (in.)		WEIGHT (lb)	FEED METHOD	CAPITAL COST
					LENGTH	WIDTH			
100	100	5		52 x 30				Top	\$23,800
400	400 ^{a/}	15		60 x 60				↓	72,400
1000	1,000 ^{a/}	40		60 x 88					139,000
2000	2,000 ^{b/}	100		60 x 98					318,000

* Throughput material for horsepower and capacity listed.

^{a/} Dual motor applications, i.e., 400 hp = 2 each 200 hp motors, etc.

^{b/} Four motor application, i.e., 2,000 hp = 4 each 500 hp motors, etc.

Capacities for municipal solid waste.

Enterprise Company
616 S. Santa Fe
Santa Ana, California 92705

Machine type: Hammermill

The Enterprise Company manufactures shredders, hoggers, and balers for paper and cardboard. Their hammermills have a unique helix arrangement of hammers so that only one hammer is striking the waste material at any one time. Their machines are top-feed and can be obtained with either bottom or side discharge. They have no units in operation processing municipal refuse; however, the installations described on the data sheet have been contracted for. The capacities shown are for corrugated cardboard and paper. The company normally sells their machines direct, although they prefer to offer a turn-key installation.

ENTERPRISE COMPANY, SANTA ANA, CALIFORNIA

MODEL NO. OR SIZE	HORSEPOWER*	CAPACITY* (TPH)	SPEED (rpm)	FEED OPENING (in.)	DIMENSIONS (in.)		WEIGHT (lb)	FEED METHOD	CAPITAL COST
					LENGTH	WIDTH			
3236EH	25 - 100	2 - 3			60	80	12,000	Top →	
3236EC	25 - 125	2 - 3			60	100	13,000		
3248EH	25 - 100	2 - 4			72	82	13,000		
3248EC	25 - 125	2 - 4			72	100	15,000		
3260EH	25 - 100	2 - 5			84	80	15,000		
3260EC	25 - 125	2 - 5			84	100	16,000		
4436EC	75 - 250	3 - 5			64	126	20,000		
4448EC	75 - 250	3 - 6			76	126	21,000		
4460EC	75 - 250	3 - 8			88	126	22,000		
4472EC	75 - 250	3 - 10			100	126	23,000		
4484EC	75 - 250	3 - 12			112	126	24,000		
5236EC	100 - 400	6 - 15			70	150	24,000		
5248EC	100 - 400	8 - 15			84	150	25,000		
5260EC	100 - 400	8 - 18			96	150	26,000		
5272EC	100 - 400	8 - 25			108	150	27,000		
5284EC	100 - 400	8 - 30			120	150	28,000		

* Throughput material for horsepower and capacity listed.

Capacities for newspaper and corrugated material.

Gruendler Crusher and Pulverizer Company
2915 North Market Street
St. Louis, Missouri 63106

Machine type: Hammermill

The Gruendler Company has been manufacturing hammermills, size reduction equipment and material handling equipment since 1885. Their machines for shredding municipal refuse are top-feed hammermills; discharge is at the bottom. They have their machines in several installations where refuse is being processed. The oldest installation is the St. Louis Municipal Refuse Plant, where municipal refuse is being shredded and used as fuel by the local electric company. They produce their hammermills in two configurations: (1) for primary size reduction; and (2) for secondary size reduction.

GRUENDLER CRUSHER AND PULVERIZER COMPANY, ST. LOUIS, MISSOURI

MODEL NO. OR SIZE	HORSEPOWER*	CAPACITY* (TPH)	SPEED (rpm)	FEED OPENING (in.)	DIMENSIONS (in.)		WEIGHT (lb)	FEED METHOD	CAPITAL COST
					LENGTH	WIDTH			
48-5				36 x 46	74	100	18,000	Top	
60-5				36 x 58	74	116	22,700		
72-5				36 x 70	74	133	25,000		
62-50	(Power and capacity to be determined upon application)			44 x 62	96	119	43,500		
72-50				44 x 72	96	129	50,000		
84-50				44 x 84	96	141	56,300		
96-50				44 x 96	96	153	62,800		
60-60				50 x 60	122	130	79,500		
84-60				50 x 84	122	154	99,300		
96-60				50 x 96	122	166	106,800		
108-60				50 x 108	122	178	113,500		
84-7				66 x 84	150	152	109,000		
108-7				66 x 108	160	176	131,000		
120-7				78 x 120	184	188	175,000		

* Throughput material for horsepower and capacity listed.

Hammermills, Inc.
625 "C" Avenue, N.W.
Cedar Rapids, Iowa 52405

Machine type: Hammermill

Hammermills, Inc., has been manufacturing size reduction equipment for over 60 years. They manufacture a full line of size reduction and materials handling equipment, including shredders, conveyors, feeders, and hoppers. The company produces numerous kinds of special purpose hammermills. Their refuse shredders have alternating short and long hammers on the rotors, and use a replaceable cutter bar. Input is side feed and they recommend a compression feed roller device to eliminate feed problems, etc. Discharge is through the bottom. They have several units in operation processing refuse and have accumulated proprietary data on operational costs. The company prefers to do a turn-key job including design fabrication and installation of the shredding facility.

HAMTERMILLS, INCORPORATED, CEDAR RAPIDS, IOWA

MODEL NO. OR SIZE	HORSEPOWER*	CAPACITY* (TPH)	SPEED (rpm)	FEED OPENING (in.)	DIMENSIONS (in.)			WEIGHT (lb)	FEED METHOD	CAPITAL COST
					LENGTH	WIDTH	HEIGHT			
4260	600	24							Side ↓	
6060	800	32								
6080	1,000	40								
74104	2,000	80								
96104	3,000	120								

* Throughput material for horsepower and capacity listed.

Capacities based on municipal solid waste.

The Heil Company
3000 W. Montana Street
Milwaukee, Wisconsin 53201

Machine type: Vertical shaft hammermill

The Heil Company manufactures a series of three refuse pulverizers based on a design similar to the English Tollemache machine, under license to the Tollemache Company. The machine is a vertical shaft hammermill with an upper conical section for primary size reduction and a lower grinding section. A unique feature of the machine is the ballistic rejection of heavy or resilient objects which are not reducible by the machine. Feed is at the top and discharge is horizontal at the bottom. The Tollemache machine has seen extensive application in Europe and Heil has several installations in the U.S. processing municipal refuse. One of the units is located at the refuse processing plant at Madison, Wisconsin. The Heil Company prefers to sell a solid waste system, including all conveyors, etc. The larger model is rated at 40 ton/hr, but no machines of this size have been built.

HEIL COMPANY, MILWAUKEE, WISCONSIN

MODEL NO. OR SIZE	HORSEPOWER*	CAPACITY* (TPH)	SPEED (rpm)	FEED OPENING (in.)	DIMENSIONS (in.)			WEIGHT (lb)	FEED METHOD	CAPITAL COST
					LENGTH	WIDTH	HEIGHT			
42D	200	15		30 x 48						
42F	250	20		42 x 60						
92A	500	40		48 x 84						

* Throughput material for horsepower and capacity listed.

Capacities based on municipal solid waste.

Jeffrey Manufacturing Company
P. O. Box 1879
Columbus, Ohio 43216

Machine type: Hammermill

The Jeffrey Manufacturing Company produces materials handling equipment. They manufacture a series of seven sizes of hammermill-type refuse pulverizers. A unique feature of their machine is the drive system. The rotor is belt driven and has a heavy flywheel to maintain speed. They do not list any installations in the U.S. for processing municipal refuse. However, their advertising literature states that throughput capacities are based on unsorted refuse.

JEFFREY MANUFACTURING COMPANY, COLUMBUS, OHIO

MODEL NO. OR SIZE	HORSEPOWER*	CAPACITY* (TPH)	SPEED (rpm)	FEED OPENING (in.)	DIMENSIONS (in.)			WEIGHT (lb)	FEED METHOD	CAPITAL COST
					LENGTH	WIDTH	HEIGHT			
432a/	100	7		32						
548a/	250	15		48						
748	400	25		48						
766b/	1,000	35		66						
770c/	500	35		70						
990c/	750	55		90						
913b/	2,000	75		102						

* Throughput material for horsepower and capacity listed.

a/ Presorting of large items required.

b/ For bulky items only.

c/ Machine capacity can be increased 12-1/2% for bulky items.

Capacities based on municipal solid waste.

Pennsylvania Crusher Corporation
Box 100 A
Broomall, Pennsylvania 19008

Machine type: Hammermill

The Pennsylvania Crusher Corporation has been manufacturing a line of material reduction equipment for over 65 years. They manufacture three lines of shredders--standard industrial, heavy duty, and bulky wastes. Their hammermill is a standard top-loading, bottom-discharge unit. The advertising literature indicates that machine capacities are based on processing refuse. The literature also indicates that they have several installations processing municipal refuse.

PENNSYLVANIA CRUSHER CORPORATION, BROOMALL, PENNSYLVANIA

MODEL NO. OR SIZE	HORSEPOWER*	CAPACITY* (TPH)	SPEED (rpm)	FEED OPENING (in.)	DIMENSIONS (in.)		WEIGHT (lb)	FEED METHOD	CAPITAL COST
					LENGTH	WIDTH			
SI2024	25	1 - 2a/		16 x 25			1,800	Top	\$ 3,600
SI3030	60	2 - 5a/		25 x 35			6,000		7,600
SI3640	125	5 - 10a/		29 x 44			8,000		9,600
SH3640	200	10 - 15b/		25 x 40			13,500		14,000
SH3666	300	15 - 20b/		25 x 60			12,500		16,000
SH4454	400	20 - 30b/		32 x 56			20,000		21,500
SH4478	600	30 - 40b/		32 x 80			28,000		28,000
SH5484	800	40 - 50b/		42 x 84			48,000		42,000
SXH6060	800	25 - 30c/		67 x 61			83,000		65,000
SXH6080	1,200	30 - 50c/		67 x 81			100,000		74,000
SXH72104	2,000	50 - 75c/		80 x 105			150,000		130,000
SXH96104	3,000	75 - 100c/		105 x 164			250,000		195,000

* Throughput material for horsepower and capacity listed.

a/ Capacity based on selected waste--density of 10 - 15 lb/ft³.

b/ Capacity based on packer truck waste--density of 15 - 20 lb/ft³.

c/ Capacity based on solid waste (except automobiles and demolition waste) at 15 - 70 lb/ft³.

Stedman Foundry and Machine Company, Inc.
Aurora, Indiana 47001

Machine type: Hammermill

The Stedman Company has been manufacturing size reduction equipment for over 50 years. They make several series of hammermills, two of which are suitable for processing municipal wastes. They have several of their machines in composting operations and being used for secondary size reduction. Their machines are top-loading, bottom-discharge types. The hammers are a reversible chisel point type.

Stedman Foundry and Machine Company, Inc.
Aurora, Indiana 47001

Machine type: Hammermill

The Stedman Company has been manufacturing size reduction equipment for over 50 years. They make several series of hammermills, two of which are suitable for processing municipal wastes. They have several of their machines in composting operations and being used for secondary size reduction. Their machines are top-loading, bottom-discharge types. The hammers are a reversible chisel point type.

STEDMAN FOUNDRY AND MACHINE COMPANY, AURORA, ILLINOIS

MODEL NO. OR SIZE	HORSEPOWER*	CAPACITY* (TPH)	SPEED (rpm)	FEED OPENING (in.)	DIMENSIONS (in.)		WEIGHT (lb)	FEED METHOD	CAPITAL COST
					LENGTH	WIDTH			
20-12				18 x 13	55	53	3,800		
20-16				18 x 17	55	58	4,150		
24-20				21 x 21	62	65	6,700		
24-24				21 x 25	62	71	7,200		
24-30				21 x 31	62	77	8,000		
30-16				26 x 17	74	67	9,500		
30-20				26 x 21	74	71	10,300		
30-24				26 x 25	74	80	11,000		
30-32				26 x 33	74	89	12,700		
36-24				32 x 25	88	87	19,000		
36-30				32 x 31	88	95	17,000		
36-36				32 x 38	88	102	19,500		
36-42				32 x 44	88	110	21,000		
42-54				38 x 56	118	99	32,400		
42-60				38 x 62	124	99	33,300		
42-84				38 x 86	148	99	35,000		

* Throughput material for horsepower and capacity listed.

Williams Patent Crusher and Pulverizer Company
2701 North Broadway
St. Louis, Missouri 63102

Machine type: Hammermill

The Williams Company is a large manufacturer of hammermills.

They manufacture an extensive line of shredders, hammermills, and related equipment. Their line of refuse shredders are top-feeding, bottom-discharge hammermills. The company has numerous installations where their machines are processing municipal solid wastes. The company prefers to do a turn-key job, installing a complete size reduction system.

WILLIAMS PATENT CRUSHER AND PULVERIZER COMPANY, ST. LOUIS, MISSOURI

MODEL NO. OR SIZE	HORSEPOWER*	CAPACITY* (TPH)	SPEED (rpm)	FEED OPENING (in.)	DIMENSIONS (in.)			WEIGHT (lb)	FEED METHOD	CAPITAL COST
					LENGTH	WIDTH	HEIGHT			

(Williams manufacturers over 30 different size basic shredders. Horsepower, capacity, feed opening, and weight are determined upon application.)

* Throughput material for horsepower and capacity listed.

APPENDIX I

EXISTING MUNICIPAL SOLID WASTE SIZE REDUCTION INSTALLATIONS

The following table presents a listing of the known installations (either operating or under construction) for size reduction of municipal solid waste. Because many of these installations are privately owned, or partially supported by federal, state, or local grants, their operational status may change at any time. For further information, first contact should be made with the machine manufacturer.

EXISTING MUNICIPAL SOLID WASTE SIZE REDUCTION INSTALLATIONS

<u>LOCATION</u>	<u>MANUFACTURER</u>	<u>SIZE</u>	<u>COMMENTS</u>
Alamosa, Colorado	Heil	20 TPH	
Altoona, Pennsylvania	Stedman		Fairfield-Hardy compost plant.
Atlanta, Georgia	American		
Brooklyn, New York	Pennsylvania Crusher	4 - 15 TPH each	Ecology, Inc., compost plant.
Chicago, Illinois	Hammermills, Inc.		Goose Island Plant
Columbus, Bartholomew County, Indiana	Heil		
Dearborn, Michigan	Williams	Model 680	
DeKalb County, Georgia	Eidal and Heil	2 each, Model 1000 3 each, 15 TPH	
Des Moines, Iowa	Enterprise		Digester Operation
Edmonton, Alberta, Canada	Eidal	Model 400	
Gainesville, Florida	Williams	Model 475	
High Point, North Carolina	Eidal	Model 1000	
Houston, Texas	Williams	Model 475	Lone Star Organics, compost plant
Indianapolis, Indiana	Hazemag		

EXISTING MUNICIPAL SOLID WASTE SIZE REDUCTION INSTALLATIONS (Continued)

<u>LOCATION</u>	<u>MANUFACTURER</u>	<u>SIZE</u>	<u>COMMENTS</u>
Los Gatos, California	Pennsylvania Crusher	3 - 30 TPH	The Sira Corporation
Louisville, Kentucky	Williams	Model 680	
Madison, Wisconsin	Heil	15 TPH	
Menlo Park, California	Eidal	Model 1000	Combustion Power, Inc.
Milford, Connecticut	Eidal	2 - Model 1000	
New Castle County, Delaware	Gruendler	4 - 50 TPH	New Castle County Public Works Department
New York, New York	Enterprise		Ponte Brothers
New York, New York	Enterprise		Meadowlands Plant
Pompano Beach, Florida	Heil	15 TPH	
Providence, Rhode Island	Eidal	Model 1000	Northeast Compost, Inc.
San Diego, California	Williams	Model 475	San Diego Public Works Department
St. Louis, Missouri	Gruendler	45 TPH	St. Louis Refuse Department
Syracuse, New York	Eidal	Model 1000	
Tacoma, Washington	Williams	Model 680	Tacoma Public Works Department

EXISTING MUNICIPAL SOLID WASTE SIZE REDUCTION INSTALLATIONS (Concluded)

<u>LOCATION</u>	<u>MANUFACTURER</u>	<u>SIZE</u>	<u>COMMENTS</u>
Vancouver, Washington	Eidal	Model 1000	Vancouver Sanitary Service
Washington, D.C.	Williams	Model 780	
Willoughby, Ohio	Eidal	Model 400	

APPENDIX II

MANUFACTURERS OF SIZE REDUCTION EQUIPMENT

Al-jon, Inc.
P.O. Box 592
Ottumwa, Iowa 42502

The American Baler Company
1000 Hickory Street
Bellevue, Ohio 44811

American Pulverizer & Crusher Company
1249 Macklind Avenue
St. Louis, Missouri 63110

Atomic Disposer Corporation
605 East Banning Avenue
Compton, California

The Bauer Brothers Company
P.O. Box 968
Springfield, Ohio 45501

Benson Industries, Ltd.
1515 Pemberton Avenue
North Vancouver
British Columbia, Canada

The Black-Clawson Company
Middletown, Ohio 45042

Buffalo Hammer Mill Corporation
1245 McKinley Parkway
Buffalo (Lackawanna), New York 14218

Buhler Brothers
8923 Wayzetta Boulevard
Minneapolis, Minnesota

Bus Boy Disposer, Inc.
13150 Saticoy Street
North Hollywood, California 91605

Centriblast Corporation
Subsidiary of the Joy Manufacturing
Company

P.O. Box 4488
Parkway West, Oliver Building
Pittsburgh, Pennsylvania 15222

Champion Line Machinery Company
229 Meadow Road
Rutherford, New Jersey

Conservomatic Corporation
113 Bala Avenue
Oreland, Pennsylvania

Consolidated Baling Machine Company
402 Third Avenue
Brooklyn, New York

Denver Equipment Company
606 Broadway
Denver, Colorado

Dorr-Oliver, Inc.
77 Havemeyer Lane
Stamford, Connecticut 06904

East Chicago Machine Tool Corporation
Balemaster Division
4801 Railroad Avenue
East Chicago, Indiana

Ecological Assistance Corporation
18-01 Pollitt Drive
Fairlawn, New Jersey 07401

Environmental/One Corporation
2773 Balltown Road
Schenectady, New York

Eidal International Corporation Subsidiary of Southwest Factories, Inc. 250 Woodward Road, S.E. P.O. Box 2087 Albuquerque, New Mexico 87103	Industrial Shredder & Cutter Company 711 South Ellsworth Avenue Salem, Ohio
The Engineer Company Teeple Place, P. O. Box 39 South Plainfield, New Jersey 07080	In-Sink-Erator Manufacturing Company 4700 21st Street Racine, Wisconsin 53406
The Enterprise Company 616 South Santa Fe Santa Ana, California	International Disposal Corporation Shawnee, Oklahoma
The Fitzpatrick Company 812 Industrial Drive Elmhurst, Illinois	Jacksonville Blow Pipe Company 2017 Thelma Avenue Jacksonville, Florida 32206
FMC Corporation Hoopeston, Illinois 60942	The Jeffrey Manufacturing Company 274 East First Street Columbus, Ohio 43216
French Oil Mill Piqua, Ohio	David J. Joseph Company 2906 Vernon Place Cincinnati, Ohio 45219
Gondard 3000 West Montana Street Milwaukee, Wisconsin 53201	Kemp Manufacturing Company 1027 East 20th Street Erie, Pennsylvania 16512
Gruendler Crusher & Pulverizer Company 2915 North Market Street St. Louis, Missouri 63106	Koehring Company 1701 West Wisconsin Avenue Milwaukee, Wisconsin 53201
Hammermills, Inc. Division of Pettibone Mulliken Corporation 625 "C" Avenue, N.W. Cedar Rapids, Iowa 52405	John S. Lane & Son, Inc. East Mountain Road Westfield, Massachusetts 01085
Hazemag Shredders Distributor: Hazemag U.S.A., Inc. 60 East 42nd Street New York, New York 10017	Logemann Brothers Company 3150 West Burleigh Street Milwaukee, Wisconsin 53245
The Heil Company 3000 West Montana Street Milwaukee, Wisconsin 53201	Luria Brothers & Company, Inc. 20521 Chagrin Boulevard Cleveland, Ohio 44122
	Master Disposers, Inc. 309 Ludlow Avenue Cincinnati, Ohio

Miller Franklin, Inc.
34 Meadow
East Orange, New Jersey

Mil-Pak Systems, Inc.
Unit of SFM (Seneca Falls
Machine) Corporation
2414 Morris Avenue
Union, New Jersey 07083

Mitts and Merrill, Inc.
Subsidiary of Waldo
American Corporation
109 McCoskry
Saginaw, Michigan 48601

Munro, H. F. & Sons, Inc.
2406 North Mascher and York Streets
Philadelphia, Pennsylvania

Newell Manufacturing Company
Box 9132
San Antonio, Texas 78204

Ogden Metals, Inc.
20521 Chagrin Boulevard
Cleveland, Ohio 44122

Oliver W. W. Manufacturing Company
8 Beard Avenue
Buffalo, New York

Pennsylvania Crusher Corporation
Subsidiary of Bath Industries, Inc.
600 Abbott Drive
Broomall, Pennsylvania 19008

Perfection-Cobey Company
Cobey Refuse Handling Division
South East Street
Galion, Ohio

The Pettibone Companies
625 "C" Avenue, N.W.
Cedar Rapids, Iowa 52405

Piezo Manufacturing Corporation
P. O. Box 120-T
Madison, New Jersey

The Proler Steel Corporation
7501 Wallisville Road
Houston, Texas

Qualheim, Inc.
1225-14th Street
P.O. Box 368
Racine, Wisconsin 53403

Richards Shear Company
7201 East Marginal Way
Renton, Washington

Ripsteel Corporation
Sales agent: Beltain-Drissen
570 Livernois Avenue
Ferndal, Michigan 48220

Salvajor Company
4530 East 75th Terrace
Kansas City, Missouri 64132

Sedberry J. B. Inc.
Dept. 83
Tyler, Texas

Somat Corporation
Box 831
Coatesville, Pennsylvania 19320

Sprout, Waldron & Company, Inc.
Muncy, Pennsylvania 17756

Stedman Foundry & Machine Company, Inc.
Subsidiary of United Engineering and
Foundry Company
Indiana and Franklin Streets
Aurora, Indiana 47001

Sturtevant Mill Company
Park and Clayton Streets
Boston, Massachusetts 02122

Swimquip, Inc.
3301 Gilman Road
El Monte, California 91732

The W-W Grinder Corporation
2957 North Market
Wichita, Kansas 67219

Tollemache
3000 West Montana Street
Milwaukee, Wisconsin 53201

Young Machinery Company, Inc.
Robinson Division
Painter Street
Muncy, Pennsylvania

Union Manufacturing & Gauge Company
511 North State
Syracuse, New York

Von Roll, Ltd.
P.Q. 2120 Sherbrooke Street East
Montreal, Quebec, Canada

Wascon Systems, Inc.
Subsidiary of Robins and Meyers, Inc.
210 Bonair Avenue
Hatboro, Pennsylvania 19040

Waste Doctors, Inc.
Subsidiary of Cumberland Engineering Company, Inc.
P.O. Box 6065
Providence, Rhode Island 02904

Waste King Universal
3300 East 50th Street
Los Angeles, California 90058

Wastex, Solar Industries

Wayne Manufacturing Company
1201 East Lexington Street
Pomona, California 91766

Wiley Miner Associates, Inc.
Box 392
Cranbury, New Jersey

Williams Patent Crusher and Pulverizer Company
2701 North Broadway
St. Louis, Missouri 63102